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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

A STUDY OF SOLAR PV POTENTIAL TO ENSURE RELIABLE SUPPLY OF AFFORDABLE ELECTRICITY IN FAVELAS, RIO DE JANEIRO, BRAZIL

THESIS TO OBTAIN THE DEGREE OF

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AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

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Abbreviations

ANEEL - Agência Nacional de Energia Elétrica - National Electric Energy Agency

BNDES - Banco Nacional do Desenvolvimento – National Development Bank

CAPM - Capital Asset Pricing Model

COFINS - Contribuição para o Financiamento da Seguridade Social - Contribution for Social Security Financing

COSIP - Contribution for the Cost of Public Lighting

IBGE - Instituto Brasileiro de Geografia e Estatística - Brazilian Institute of Geography and Statistics

ICMS - Imposto Sobre a Circulação de Mercadorias e Serviços - Tax on Circulation of Goods and Services

IPP - Rio de Janeiro Municipal Institute of Urbanism

IRR – Internal Rate of Return

MME - Ministry of Mining and Energy

NPV - Net Present Value

PIS - Programa de Integração Social - Social Integration Program

TSEE - Tarifa Social de Energia Elétrica - Social Tariff of Electric Energy

UPP - Unidade de Polícia Pacificadora - Pacifying Police Unit

WACC - Weighted-Average Cost of Capital

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Abstract

With a rapidly growing population and urbanization, most modern slums (favelas) also proliferated in Brazil since the 1950s when many people left rural areas of Brazil and moved into the cities. Rio de Janeiro is one of those cities having a vast amount of favelas with poor living conditions. One of the main problems of electricity supply in favelas is illegal electricity use, called 'Gato' in Portuguese. Recent unexpected severe drought, economic crisis, and rapidly increased electricity price in Brazil affected the reliable supply of affordable electricity in favelas.

Considering abundant solar radiation of the country and the government's willingness trying to shift the framework of energy supply from hydropower to renewable energy, this study analyzes the solar PV potentials to ensure a reliable supply of affordable electricity in favelas in Rio de Janeiro.

Literature reviews regarding solar PV development in Brazil, energy policy analysis in Brazil and electricity issues in favelas are revised. As a case study, the chosen favela 'Babilônia' are presented. The survey analysis about electricity consumption situation with social dimension targeting residences in Babilônia is implemented. Lastly, through economic analyses with cost-benefit calculation such as Internal Rate of Return (IRR), Net Present Value (NPV), Discounted Cash Flow, Payback period, Capital Asset Pricing Model (CAPM) and Weighted-Average Cost of Capital (WACC) models, this study develops the possible financing alternatives to implement a solar PV project with different scenario analyses in the current solar PV market and solar energy policy of Brazil.

The results of this study can be used as an aid to comprehend the electricity supply issue of the most vulnerable class in Brazil and the solar PV as a solution.

Key words: Solar energy, Solar PV, Electricity supply, Electricity theft, Favela

Resumen

Debido al rápido incremento poblacional y su urbanización, un alto número de favelas modernas han proliferado en Brasil a partir de la década de 1950, cuando la población rural fue forzada a emigrar hacia entidades urbanas. Rio de Janeiro es actualmente una de estas ciudades, pues cuenta un gran número de asentamientos con baja calidad de vida. Uno de los mayores problemas dentro de estas favelas es el uso ilegal de la electricidad, llamadas “Gato” en portugués. Una severa e inesperada sequía, la crisis económica y un rápido aumento de costo para contar con electricidad dentro de Brasil, han afectado el suministro confiable de electricidad accesible en las favelas.

Considerando la abundante radiación solar del país y la voluntad gubernamental para modificar el contexto legal y beneficiar el suministro de energía renovable a cambio de la hidroeléctrica; este estudio pretende analizar el potencial de la energía solar fotovoltaica y garantizar un suministro accesible de electricidad para las favelas de Río de Janeiro.

Revisiones literarias sobre el desarrollo de la energía solar fotovoltaica en Brasil, un análisis sobre la política energética dentro de Brasil y los problemas de electricidad en las favelas serán llevados a cabo. Como caso de estudio, se ha elegido una favela llamada ‘Babilônia’. Para este caso de estudio, han sido implementadas encuestas que abarcan el consumo eléctrico dentro de este centro poblacional, así como la dinámica social que genera este consumo. Así mismo, fueron llevados a cabo análisis para abarcar el costo-beneficio en este ámbito; herramientas como Tasa Interna de Retorno (TIR), Valor Actual Neto (VAN), Flujo de Caja Descontado, Periodo de Recuperación, Modelo de Valoración del Precio de los Activos Financieros (CAPM) y Costo de Capital Promedio Ponderado (CCPP) fueron implementados. Este estudio comprende, de igual manera, diversas posibilidades para hacer posible el financiamiento de proyectos de solar fotovoltaicas en distintos escenarios en el mercado de energía solar actual y política de energía solar regente en el país.

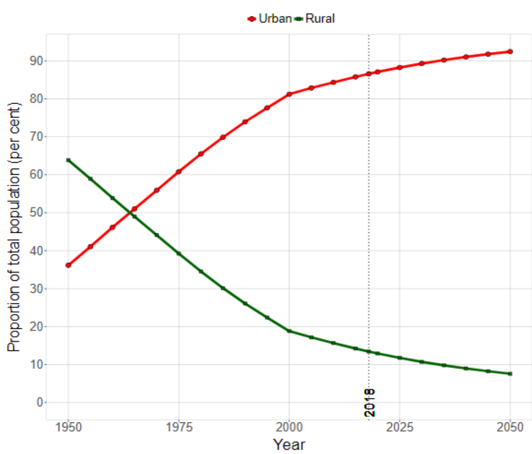
Esta investigación, se propone como una herramienta para comprender y abordar las necesidades dentro de las favelas en Brasil, debido a su vulnerabilidad y, de esta manera, proponer de una manera sustentable la implementación de la energía solar fotovoltaica.

Palabras claves: Energía solar, Solar fotovoltaicas, Suministro eléctrico, Robo de electricidad, Favela

1. INTRODUCTION

1.1. Background

In 2016, an estimated 0.9 billion people –13% of the world population– did not have access to electricity (The World Bank, 2018). This situation was the result of two causes: accelerated population growth rates; and rapid urbanization since 1950, that continued up to the present so that the global urban population (50.46%) exceeded the global rural population (49.54%) in 2008. Therefore, with the advent of accelerated urban population growth and rapid urbanization, we also attest to the rapid pace of slum construction in world megacities, mainly in developing and poor countries. Latin America, including the Caribbean islands, is the second most urbanized region in the world with 80 per cent of its population living in urban areas (United Nations, 2015). In this context, with a rapidly growing world population and urbanization, most modern slums (favelas) also proliferated in Brazil since the 1950s when many people left rural areas of Brazil and moved into the cities (Figures 1a,1 b). Unable to find comfortable and safe built places to live, many people found themselves dwelling in favelas, with poor living conditions because of the lack of water, electricity, sewage, paved roads, schools, hospitals, and so on.



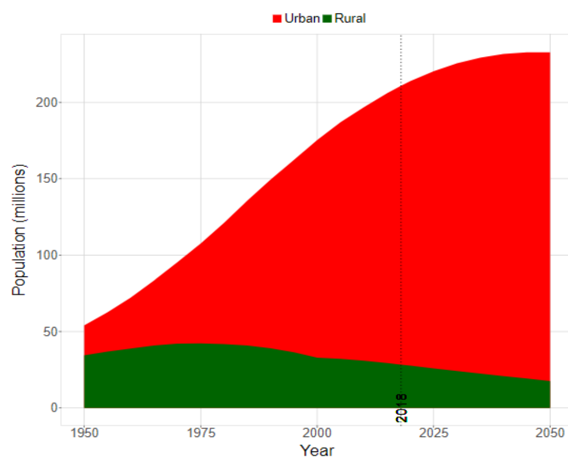


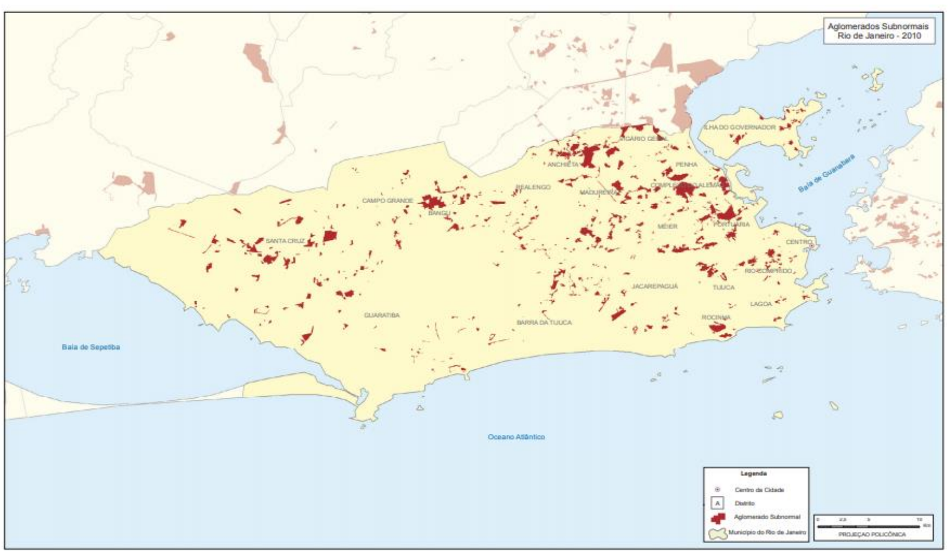
Figure 1a. Urban and rural population growth in Brazil in percentages

Figure 1b. Urban and rural population growth in Brazil in millions of inhabitants

Source: United Nations DESA

A favela is a Portuguese word used to define slum. The characteristics that the IPP (Municipal Institute of Urbanism in Rio de Janeiro) considers to define an area as favela are: 1) irregular land occupation; 2) lack of formal property titles, which does not mean that the occupation is illegal; 3) urban fabric arranged irregularly; 4) small and indefinite lots; 5) narrow roads; 6) precarious sanitation infrastructure; 7) insufficient or non-existing social equipment; 8) housing in disagreement with standards; 9) lack of special urban planning rules. Strictly speaking, existing urban norms should be applied to each entire neighborhood, but this is not the case in favelas; 10) no real estate properties registered in the cadastral records; 11) predominance of low-income population (Prefeitura da Cidade do Rio de Janeiro).

In 2010, favela residents were about 11.4 million, which amounted to 6% of the Brazilian population. The number of favelas were 6,329 and almost half (49.8%) of them were distributed in the South-east Region. The state of Rio de Janeiro, the third most populous in Brazil, has 1,332 favelas, which is almost 20% of the total number of favelas of the country. In Rio de Janeiro, the older settlements were located in downtown and surrounding districts, where the job offers were concentrated (Map 1) (Instituto Brasileiro de Geografia e Estatística [IBGE]).



Map 1 Distribution map of favelas in Municipality of Rio de Janeiro – 2010

Source: (IBGE)

Indeed, there are many areas in favelas which the central/local government cannot control. As a consequence, it is often found that there are factual powers (such as drug cartels) which have more power than the government leading to favela self-government. In this situation, drug lords established tight territorial control, often denying the favela population access to basic services such as fresh water, sanitation, energy, or healthcare, since public utilities providers refused to serve areas where the integrity of their infrastructure and employees could not be guaranteed by the state.

Type of service	Percentage of adequate permanent private housing units (%)		
	Irregular urban areas of municipalities	Regular urban areas of municipalities	
		With subnormal agglomerates	Without subnormal agglomerates
Water supply	88.3	92.9	91.3
Sewage disposal	67.3	85.1	65.6
Garbage disposal	95.4	98.6	96.3
Electricity energy	72.5	88.5	91.3

Table 1 Public basic service suppy by housing type in 2010

Source: (IBGE)

Table 1 shows that there is a broad distinction regarding the access to basic services between irregular urban areas such as favelas and regular urban areas of municipalities. Electricity supply has an apparent gap between irregular urban areas (72.5%) and regular urban areas (88.5%/91.3). The adequacy of the electrical energy service – supplied with exclusive meters monitoring– reached only 72.5% of the households in irregular urban areas. These numbers show that, while electricity supply is generalized in the irregular urban areas, electrical energy supply faces quality, safety and regularization issues (IBGE).

Thus, residents often resorted to unconventional solutions to access this basic service. In the case of electricity, the solution was to steal it directly from the overhead cables, at the risk of electrocution (Figure 2). Electricity is stolen by “gato” (in Portuguese meaning the illegal high-jacking of power) that is plugged onto the electric supply to draw off power. However, even though some favelas in Rio de Janeiro have stable access to electricity provided by supply companies after favela pacification program (Police Pacifying Unit – UPP) since 2008, some residents still prefer to stick to the illegal electricity use in order to avoid paying the electricity bill, which is considered significantly high for their income levels.

Figure 2 Electric cables in the ‘Babilônia’ favela, Rio de Janeiro, 2018

(Photo: own photograph)

Consequently, this practice encourages wasteful habits, increase in environmental damages, increase in the risk of short circuit, breaking equipment, no law-abiding behavior, which affects the total cost of bills in the end. Vieira da Silva (2003) points out that energy consumption in the favelas performs disorganized not only because it is stolen, but also because the clandestine use encourages wasteful habits (Tatiana Lauria Vieira da Silva, 2003). In the concession area of Light, which is the only power supplier in the city of Rio de Janeiro, the volume of stolen energy reaches 20%. Of those, 52% of the energy is stolen outside the risk areas, in regions where the company is able to operate. The remaining volume 48% is concentrated in risk areas, where the company has severe operational restrictions due to lack of security (area of drug trafficking and militia) (Light, 2018a). In some favelas such as Rocinha and Maré in Rio de Janeiro, electricity theft can reach more than 85% of all electricity consumed by each favela (Light, 2018b). These high numbers can be easily related with socio-economic factors like distrust, informal social rules, corruption, bribery, social unawareness and high electricity prices. In this complex social-economic context relating to the electricity supply to dwellers in favelas, considering the abundant solar PV potentials and developing its use could be measured to solve the problem.

1.2. Justification

1.2.1. Unexpected severe drought

Brazil has been extremely dependent on the hydropower for electricity generation, which is almost 70% of the total production, whereas the world average is around 16% (Sperling, 2012). Brazil has the largest installed hydropower capacity in South America, and comprises two thirds of the continent's installed capacity, at 100,273 MW. The Brazilian hydropower generation is 401,060 GWh in 2017 (International Hydropower Association, 2018). Although the non-hydro renewable energy such as solar, and wind have increased gradually, it still remains a small portion of total electricity generation (Figure 3).

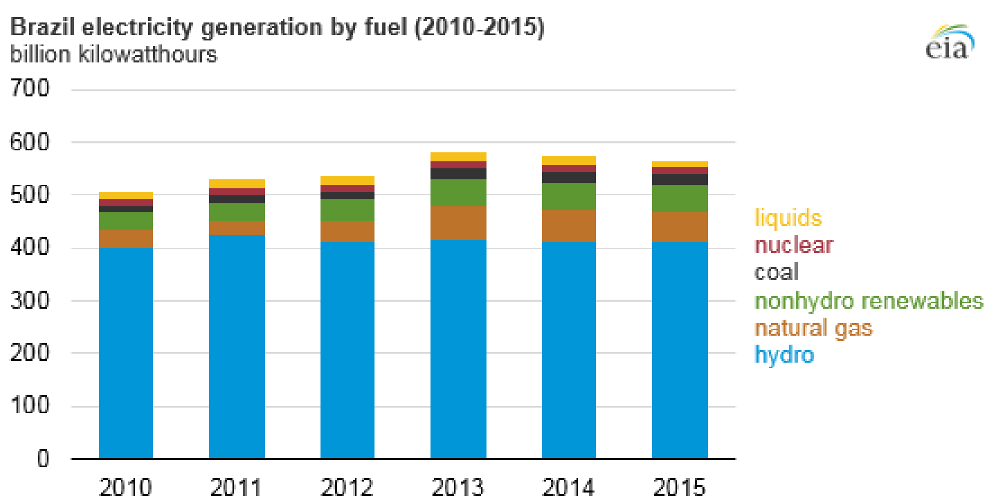
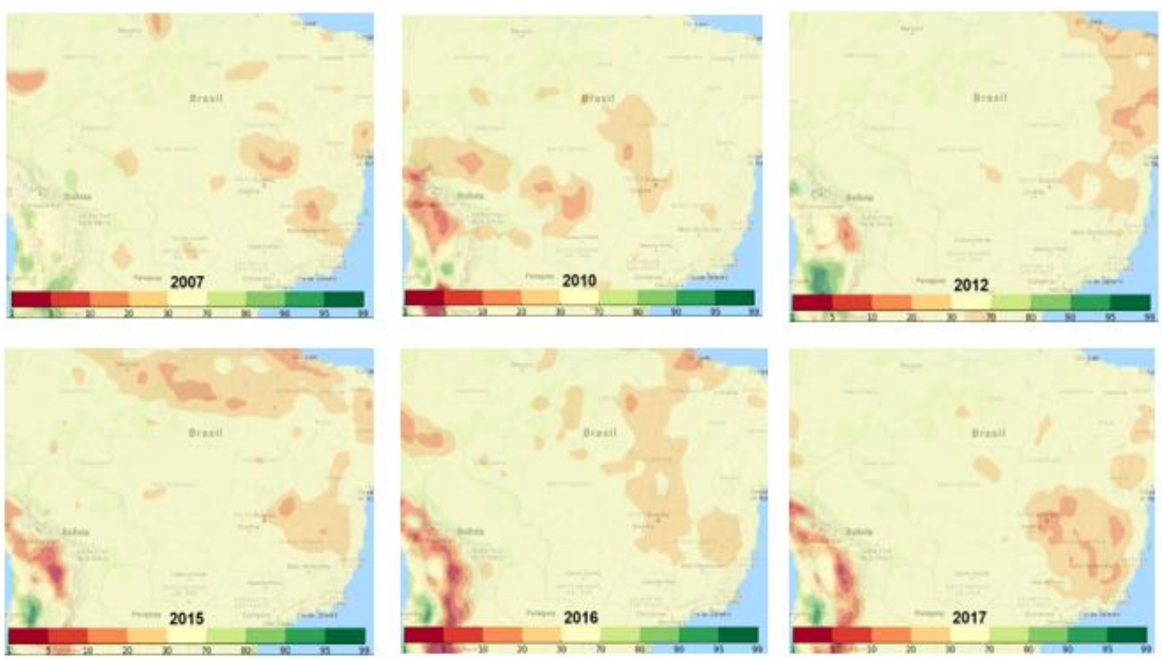


Figure 3 Brazil electricity generation by fuel (2010-2015)

Source: (EIA, 2016)

However, the long-term drought has overwhelmed Brazil and resulted in a negative effect on hydroelectric power generation (Map 2). The year 2017 was recorded as the fourth consecutive year of a severe drought in various parts of the country impacting reservoir levels. Recently, the South-eastern part of Brazil experienced a three-year drought that was exacerbated by the strong 2015–16 El Niño event, which made it the worst water shortage event in the region in 35 years (EIA, 2016). Considering that the majority of Brazil's electricity is generated by hydropower, there is alarm that a lack of water might cause a crisis to energy supply, in addition to water supply crisis. Drought conditions reduced hydropower consumption output in Brazil by 5.5% in 2014 (Map 2) (BP, 2015). Population and the farming sector suffered owing to the shortage of water. Additionally, major cities had blackouts due to lowered hydroelectricity generation and high demand such as consumption of air conditioning due to high temperatures. To compensate, thermoelectric power plants, which are more expensive than hydropower, and imports from Uruguay and Argentina, have reinforced electricity supplies (International Hydropower Association, 2018).



Map 2 Drought monitor map from 2007 to 2017 in Brazil

Source: (Latin American Flood and Drought Monitor)

Consequently, severe drought brings about a surcharge on electricity rates and this increase significantly affects the household economy of residents especially in Favelas. However, given this current situation that energy supply in Brazil relies heavily on renewable energy source (hydropower generation), the production of energy greatly depends on climatic conditions, which may be impacted in the future due to global climate change (Lucena et al., 2009). Therefore, this is the time to reconsider the expansion of hydropower plant projects and to seek for better solutions to overcome the forthcoming energy crisis.

1.2.2. Recent economic crisis in Brazil

Brazil has been suffering a tremendous economic crisis since 2014 linked to the political unrest. The GDP per capita growth (annual %) rose up to 6.5% in 2010 but it decreased down to -4.3% in 2014 (The World Bank Data, 2018). At the same time, the average inflation rate was 5-6% from 2008 to 2014 but it increased up to 9.03% in 2015 (OECD Data, 2018). Indeed, the interest rate from the central bank was 8% in 2013 and increased up to 14% in 2016 (Figure 4) (Banco Central do Brasil, 2018).

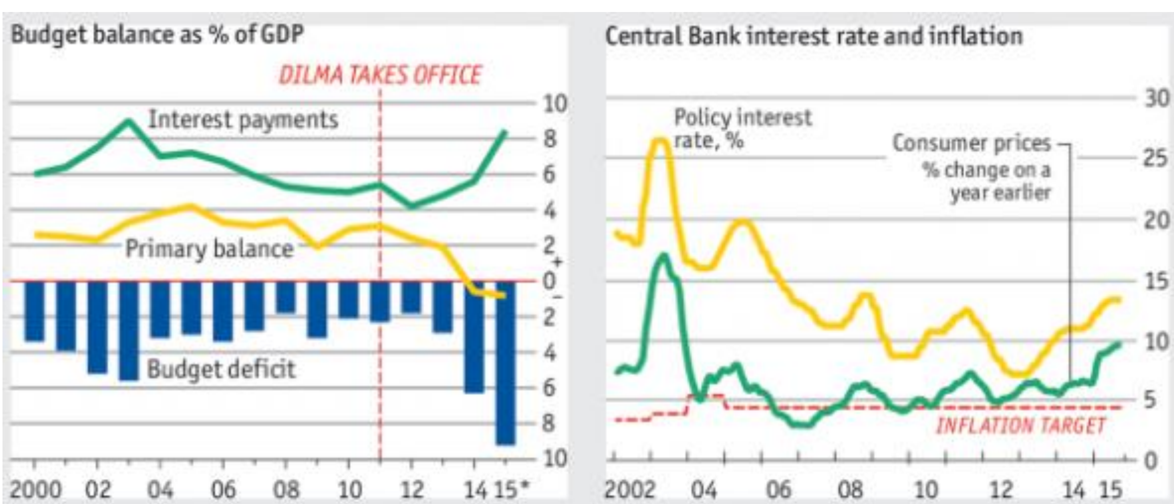


Figure 4 Budget, interest and inflation in Brazil, 2000-2015

Source: (The Economist, 2016)

In 2011, the ex-president Dilma Rousseff, increased public expenditure, raised the minimum salary and forced the state-owned banks to lend more. In addition, the central bank dropped the discount rate from 11.5% to 7.25%, which caused inflation. Price controls negatively influenced the revenues of the state-owned oil company, Petrobras and business sectors shortened investment in the wake of this government intermediation. Intervening in the electricity and banking industries also worsened the economic condition. Due to the reduced investment for private sectors and financial aggravation from public sectors, the unemployment rate was exacerbated. It gradually decreased from 2007 to 2014 (10.9% → 6.8%) but dramatically soared from 2015 to 2017 (8.5% → 13.4%) (Figure 5) (Statista, 2018).

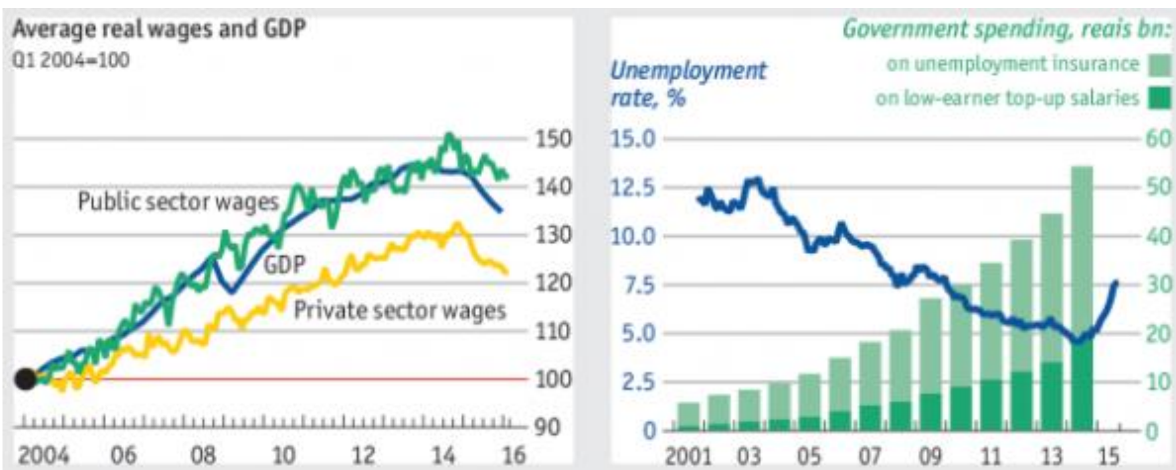


Figure 5 Wages and jobs in Brazil, 2001-2016

Source: (The Economist, 2016)

Especially, the state of Rio de Janeiro had more severe problems. The state declared a financial calamity before the Olympics in 2016. The main cause was spending excessive budget for improving the city's infrastructure such as transport, housing and policing but also it arose from the crisis on a tax deficit with the strong recession from the country. In the end, focusing on the mega event brought about that civil servants and pensioners were unpaid their salary in arrears. In conclusion, all those mentioned economic crisis affected much more roughly for vulnerable social group like residents in favelas by driving them into a corner.

1.2.3. Rapidly increased electricity price

During Q2 2018, the price of electricity in Brazil was R$ 0.667 which was equivalent to 0.181 USD at the exchange rate at the time of collecting the data. During the same time, the world average price was 0.177 USD per kWh of electricity used. These numbers are based on annual household consumption of 2100 kWh (Global Energy Prices, 2018). The electricity price has been rising up so rapidly and its amount is absurd for the vulnerable class.

In the case of the city of Rio de Janeiro, Rio's local company 'Light', which is the monopoly supplier for electricity and was privately owned since 1996, makes more vulnerable to have stable supply condition. Since 2008, UPP started to be implemented in favelas and the improved public safety helped Light to access to reform the electricity network, especially installing new digital consumption meters for each house (Figure 6). The main reason was to avoid the illegal electricity use and to manage the clients in more effective way. To do so, the network was covered by a shield box, disturbing illegal connections on poles. Indeed, a digital display for checking consumption was provided to inhabitants in order to prevent the interfering of the meters' sticks. After that, a number of residents have reported that the electricity bill soared even more than 10 times, which is not affordable with their salary and this status quo let people distrust Light provoking big conflict between them.

Figure 6 Digital meters in Babilônia, Rio de Janeiro, Brazil

(Photo: own photograph)

1.3. Research Questions

Regarding the execution of this study, there are several questions to be examined mainly about specific situations in favelas and solar energy conditions in Brazil.

- What is the practicable methods to ensure reliable supply of affordable electricity in favelas in Rio de Janeiro in Brazil by taking advantage of abundant solar PV potentials?
- What are the risks of implementing and maintaining PV in favelas? (theft, breaking, installation, law revision, etc.) Above all, if there is no income for the residents due to the ongoing economic crisis in Brazil, how can they pay back the loan for PV panels?
- At what extend solar energy can help to diminish electricity problems in the Brazilian favelas?
- Is installing PV in favelas on hillside safe considering possible heavy natural disaster such as landslide, flood or heavy rain? When it rains for a long time, how can we manage using PV?
- What are the possibilities of building a solar energy proposal in favelas in the current legal framework?

- How favela dwellers could get interested in solar electricity if they already get electricity for free? In other words, how this solar energy strategy could be sold to the favela dwellers as potential benefits?
- What are the effective ways to lead social participation in favelas?

1.4. Objectives

1.4.1. General objective

To Investigate the potential role of solar PV in favelas in Rio de Janeiro, Brazil and seek for the proper financing models in Babilônia.

1.4.2 Specific objectives

- To examine the status quo of the solar PV potentials and trends in Brazil.
- To identify the political/institutional status about solar energy in Brazil.
- To analyze the social/political/economical condition of favelas and related issues regarding electricity supply.
- To develop the feasible financial models of implementing solar PV in Babilônia.

1.5. Analytical structure

This study approaches with the following four main parts.

- **General sector analysis with literature reviews**

- Solar PV development in Brazil: Analyzing how many potentials of solar PV exist in Brazil and verifying the supply and demand of solar energy are the principal part which should be examined before developing this study.

- Energy policy analysis: Energy transition is not a matter of only technical part but also policy part. Without the proper and well-designed political decisions, expanding the solar PV would not be simple. Also, considering the fact that Brazil is an enormous country, it is necessary to analyze the energy policy separately – the national and the state level. Figuring out the energy policy trend from the past and newest law/policy would contribute to understand the optimal approach with economic utility.

- Electricity issues in favelas: This part focus on the electricity problems on favelas in Brazil. It is comprised of three parts - energy efficiency, electricity theft and social participation.

- **Case study**

With the likely result of this investigation, local/central governments, companies, and organizations can have new alternatives to supply and consume electricity in favelas. In addition, the adoption of new solar technologies aligned with social interactions in all parts of its implementation could enhance the impacts on the dweller's living conditions, and at the same time, on the government's efficiency and on the environment. Finally, by involving stakeholders such as local governments and local people from favelas to become part of the solution, it could raise the chances to offer an economically, socially and environmentally better future for the favela dwellers. In this part, interviews and surveys will be used to comprehend the actual situation.

- **Survey analysis**

A local NGO 'Revolusolar' has been conducting their solar PV project in Babilônia Community, Rio de Janeiro since 2016. The survey was conducted by Revolusolar from April to September in 2017 targeting residents in Babilônia. The questionnaire comprises four main categories: 1) Electricity consumption by each electrical appliance, 2) Expenses of electricity bill by Light, 3) Social dimension of households, 4) Social dimension on solar energy and interests in cooperative. The result of this survey will be used to understand the social and economic aspect with electricity consumption and the payment possibilities of the residents which is necessary to apply for the finance models of solar PV project on this study.

- **Economic analysis in Babilônia**

Developing various financing models will be conducted using Cost Benefit Analysis with analytical tools such as Internal Rate of Return (IRR), Net Present Value (NPV), Discounted Cash Flow, Payback period, Capital Asset Pricing Model (CAPM) and Weighted-Average Cost of Capital (WACC) models. Several assumptions such as different interest rate, higher electricity tariff increase, more subsidy for social tariff and cooperative models are used to calculate the scenario analysis

2. METHODOLOGY

This study is developed mainly in three methods with a quantative/qualitative approach.

Firstly, literature reviews regarding solar PV trend, solar energy policy in Brazil and electricity issues in favelas are studied to look into the potentials and the base condition of the country before analyzing the case study.

Second, expert interviews and a survey targeting residents in a favela are applied to comprehend the current situation of the project site. For this, I interviewed key social actors involved in the scheme such as an ex-employee of the power supplier Light, professors from universities in Rio de Janeiro, the residents in a Babilônia. Also, I analyzed a survey which was conducted by local NGO Revolusolar targeting residents in Babilônia. The result of this survey is used with descriptive statistics.

Finally, cost-benefit analysis of installing solar PV in the community will be conducted. Several analytical tools such as Internal Rate of Return (IRR), Net Present Value (NPV), Discounted Cash Flow, Payback period, Capital Asset Pricing Model (CAPM) and Weighted-Average Cost of Capital (WACC) models are used. To start the calculation, I refer some result of the survey analysis such as the consumption of the monthly amounts of kWh and income of households. A specific electricity bill which has the average amount of electricity consumption of survey is used as a sample household. Thus, I verify more detailed information about this house regarding solar energy potentials by using the website ‘America do SOL’. I also use another website ‘Portal Solar’ to find the actual prices of solar system equipment.

3. LITERATURE REVIEW

3.1. Solar PV development in Brazil

Brazil is the second Latin American country to cross the 1 GW mark of installed PV capacity after Chile. According to statistics released by the local solar association ABSOLAR, the country has reached a cumulative installed solar power of around 1,099.6 MW, of which 935.3 MW is represented by large-scale solar plants, and 164.3 MW by distributed generation PV power generators (up to 5 MW). As for the large-scale segment, a strong increase in capacity was due to the commissioning of solar facilities contracted by the federal government in electric power auctions it held in 2014 and 2015 (EMILIANO BELLINI, 2018). Another important feature is solar radiation. Because of its mid-latitude geographical location, Brazil is privileged with abundant solar radiation, where the sun rises on average 280 days a year (Isabelle de Souza Cabral, 2013). The Brazilian region that yearly receives the least sunlight gets around 1642 kWh/m², which are above the values of the German region that gets the highest annual sunlight rate about 1300 kWh/m² (Isabel T. SALAMONI, 2007). Measurements of solar radiation indicate that Brazil receives more than enough sunlight to meet the nation's projected energy demand through the use of photovoltaic (PV) energy generation, which converts sunlight to electricity (EPE, 2014). In addition, Brazil has one of the largest silicon reserves in the world, an important material used to produce solar PV panels.

Even when conventional utilities offer service, there are some advantages to solar PV energy technologies, which include:

- Modularity, providing redundancy and resilience in the event of failure of utility supply;
- Low or no fuel requirements;
- Life-cycle costs which can be less than for equivalent service from fossil fuel options;
- Hybrids which can provide 24-hour high-quality power; and
- Less maintenance and provide greater reliability than diesel generators in many field conditions (U.S. Agency for International Development, 2002)

Research and development progresses have lowered PV costs dramatically. In Figure 7, the graph demonstrates the descending trend of PV module costs, which were reduced approximately 5 times in 15 years ($ 3.8 -> $ 0.7). Although the costs are still high, they continue to decrease.

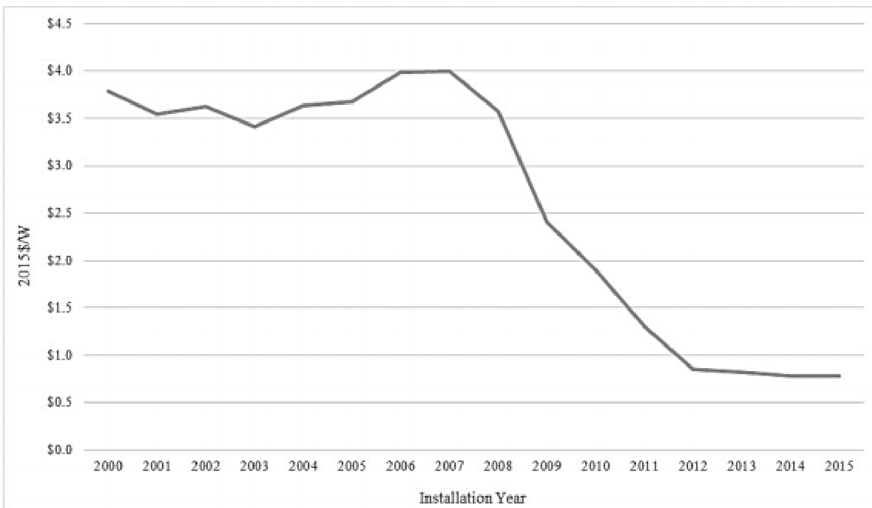
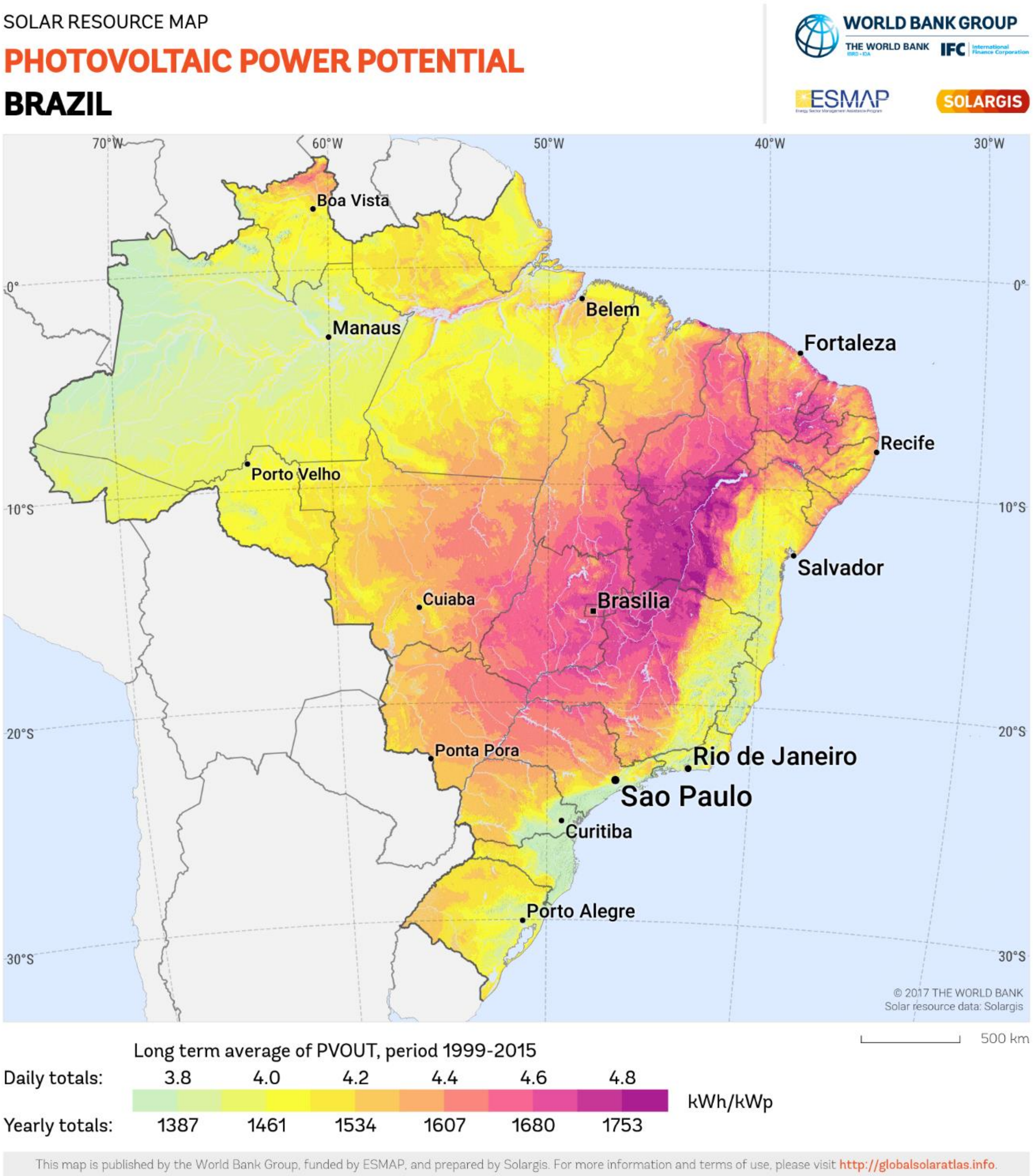


Figure 7 Module Price Index over Time for Residential PV Systems

(Source: Barbose & Darghouth, 2016)



Map 3 Photovoltaic power potential in Brazil

(Source: World Bank Group)

3.1.1. Supply/demand of solar PV

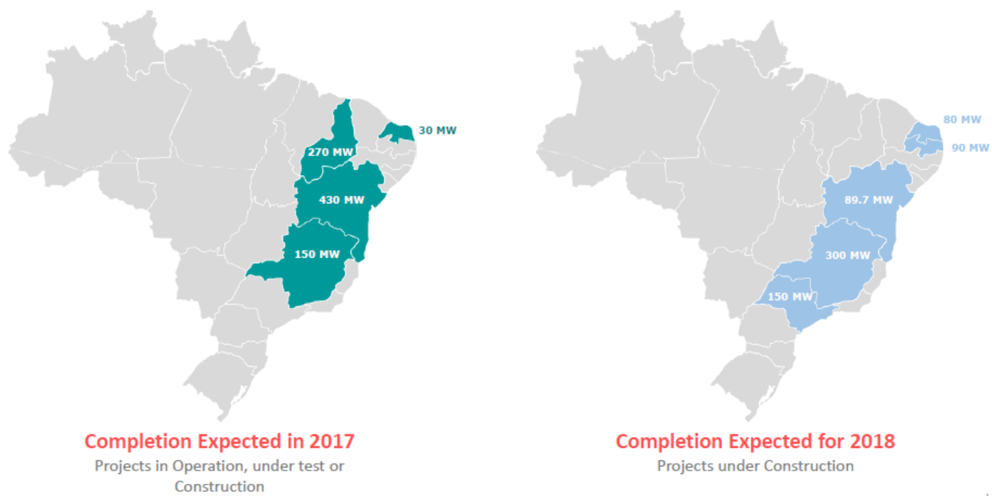
Brazil's solar insolation resources could yield impressive medium-term growth opportunities. By 2024, Brazil forecasts that it could bring up to 7 GW of solar generation capacity. BNDES alone (Brazilian Development Bank) expects to invest US$ 2.5 billion in solar development through 2018. With a solar distributed generation regulation already in place, investments in this area alone could reach US$ 25 billion by 2030 (Export.gov, 2017).

In 2014, there was the first ANEEL's auction for solar source and 1,048 MWp were contracted in the 6th reserve energy auction (LER – Leilão de Energia Reserva). Additionally, 2,159 MWp were contracted in 7th and 8th reserve energy auctions in 2015. Then the two reserve energy auctions announced it cancellation in 2016. In the 25th new energy auction (LEN - Leilão de Energia Nova) in 2017, 790.6 MWp of PV were contracted (Table 3).

	6th Reserve Energy Auction (2014/Oct-31) LER 2014	7th Reserve Energy Auction (2015/Aug-28) 1th LER 2015	8th Reserve Energy Auction (2015/Nov-13) 2th LER 2015	25th New Energy Auction (2017/-Dez-18) LEN A-4
Contracted Power (MWp)	1,048.2	1,043.7	1,115.9	790.6
Contracted Power (MWac)	889.7	833.8	929.3	574
Average Sale Price (R$/MWh)	R$ 215.12/MWh	R$ 301.79/MWh	R$ 297.75/MWh	R$ 145.60/MWh
Average Sale Price (US$/MWh)	US$ 87.80/MWh	US$ 85.98/MWh	US$ 78.77/MWh	US$ 44.25/MWh
Exchange Rate	R$ 2.45/US$	R$ 3.51/US$	R$ 3.78/US$	R$ 3.29/US$
Start of Energy Supply	01/10/2017	01/08/2017	01/11/2018	01/01/2021
Capex* Average (R$/MWp)	R$ 3,953,660.56	R$ 4,162,392.44	R$ 3,940,245.77	R$ 4,874,861.17
Capex* Average (US$/MWp)	US$ 1,613,739.00	US$ 1,185,866.79	US$ 1,042,393.06	US$ 1,481,720.72

Table 2 Summary of ANEEL auctions

(Source: Greener, 2018)



Map 4 Projects in operation, test or construction

(Source: Greener, 2018)

Map 4 presents the solar energy projects in operation, test or construction in 2017 and 2018. What we can check from this data is that most of solar energy projects works in the south east region of the country.

3.1.2. Development of solar PV market trend

There is an evident difference of prices between imported and domestic products. It is often cheaper for companies to import solar components from abroad.

- Local modules

Local produced modules (Table 4) are an option for the current and future entrepreneurs in the sector. As the costs are 35% to 45% higher than the imported modules, the PV projects using local modules requires favorable financing conditions provided by development banks. Although locally assembled, the local modules depend on imported parts which is subject to the direct impact of the exchange rate.

Scenarios	2017	2018	2019	2020
Local Modules (US$/Wp)	US$ 0.660/Wp (include taxes)	US$ 0.633/Wp (include taxes)	US$ 0.624/Wp (include taxes)	US$ 0.614/Wp (include taxes)
Local Modules (R$/Wp)	R$ 2.106/Wp (dollar base R$3.19)	R$ 2.088/Wp (dollar base R$3.30)	R$ 2.058/Wp (dollar base R$3.30)	R$ 2.027/Wp (dollar base R$3.30)

Table 3 Scenarios of local modules cost from 2017 to 2020

(Source: (Greener, 2018b))

- Imported modules

Used by most Utility Scale Projects, imported modules (Table 5) feature substantially lower costs than the local modules, however they limit or prevent access to resources of development banks. The strong rise in current market prices draws special attention, as well as limitations on availability reported by some entrepreneurs.

Scenarios	2017	2018	2019	2020
Imported Modules (US$/Wp)	US$ 0.472/Wp (include taxes)	US$ 0.452/Wp (include taxes)	US$ 0.445/Wp (include taxes)	US$ 0.439/Wp (include taxes)
Imported Modules (R$/Wp)	R$ 1.504/Wp (dollar base R$3.19)	R$ 1.491/Wp (dollar base R$3.30)	R$ 1.470/Wp (dollar base R$3.30)	R$ 1.448/Wp (dollar base R$3.30)

Table 4 Scenarios of imported modules cost from 2017 to 2020

(Source: (Greener, 2018b))

To comprehend the general situation of solar PV market in Brazil, I referred the quarterly report from Greener. Greener elaborated its market research by interviewing 552 integrating companies from November 29, 2017 to January 2, 2018. The survey counted on sampling of companies from all over the country, all sizes and ages, obtained from a reliable sample of the integration market.

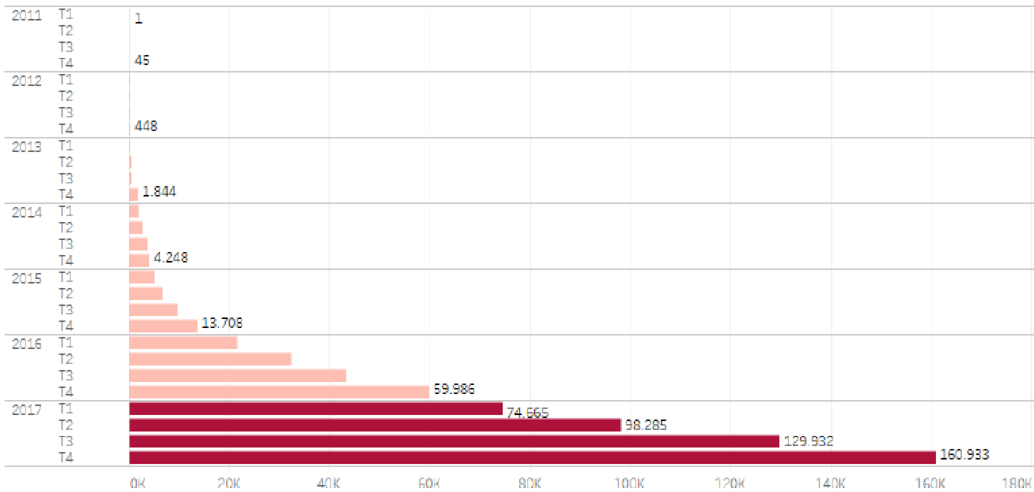


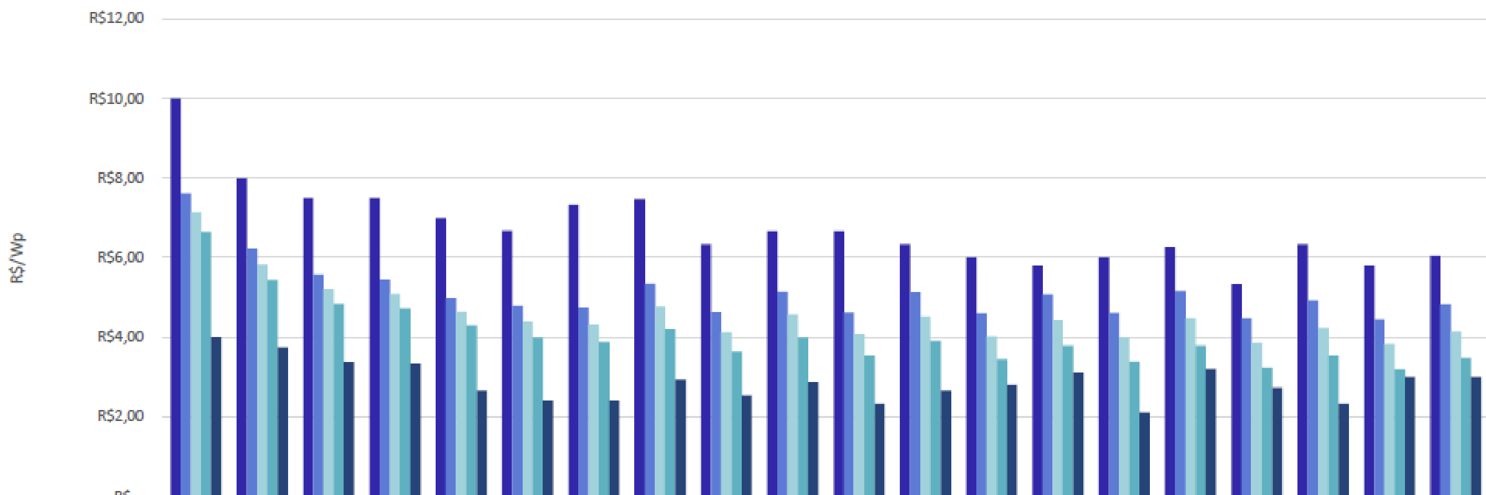
Figure 8 Total accumulated solar power connected to the network (kWp)

(Source: (Greener, 2018a))

As we can see on the figure 8, the total accumulated solar power connected to the network has tripled in one year comparing the fourth quarter in 2016 and 2017. Since the legal framework related to solar energy enacted more practically in 2012 and 2015 (Resolution 482/2012 Resolution 687/2015), it is conservative to say that the growth of solar energy in Brazil will steadily increase for the next years.

Most of solar power were distributed to the residential and commercial use and very little amount of power were used to industrial, rural, public power, public service and street lighting. Resolution 482/2012 and Resolution 687/2015 have characteristics to facilitate the growth of mini and micro power generation plants so that we can assume that this tendency would be similar or stronger in the future (it is written more specifically in the chapter of 'National/state analysis').

It is noted that most of the company headquarters are located in the Southeast region concentrating more than 50% (Greener, 2018a). It is reasonable considering the map of photovoltaic power potential in Brazil which shows that this region has the highest potential of the country. Additionally, the Southeast region is the richest and the most modernized area of the country.



	2 kWp	4 kWp	8 kWp	12 kWp	30 kWp	50 kWp	75 kWp	75 kWp ao Solo	150 kWp	150 kWp ao Solo	300 kWp	300 kWp ao Solo	500 kWp	500 kWp ao Solo	1 MWp	1 MWp ao Solo	3 MWp	3 MWp ao Solo	5 MWp	5 MWp ao solo
Maior Preço	R$10,00	R$8,00	R$7,50	R$7,50	R$7,00	R$6,68	R$7,33	R$7,47	R$6,33	R$6,67	R$6,67	R$6,33	R$6,00	R$5,80	R$6,00	R$6,26	R$5,33	R$6,33	R$5,80	R$6,04
Preço Médio Máximo	R$7,61	R$6,22	R$5,57	R$5,45	R$4,98	R$4,79	R$4,75	R$5,34	R$4,62	R$5,15	R$4,62	R$5,14	R$4,60	R$5,07	R$4,61	R$5,16	R$4,48	R$4,92	R$4,45	R$4,83
Preço Médio	R$7,13	R$5,83	R$5,21	R$5,09	R$4,64	R$4,39	R$4,31	R$4,77	R$4,13	R$4,57	R$4,07	R$4,52	R$4,02	R$4,43	R$4,00	R$4,47	R$3,85	R$4,22	R$3,82	R$4,15
Preço Médio Mínimo	R$6,65	R$5,44	R$4,85	R$4,72	R$4,29	R$3,99	R$3,88	R$4,20	R$3,64	R$4,00	R$3,53	R$3,90	R$3,44	R$3,78	R$3,39	R$3,79	R$3,23	R$3,53	R$3,20	R$3,47
Menor Preço	R$4,00	R$3,75	R$3,38	R$3,33	R$2,67	R$2,40	R$2,40	R$2,93	R$2,53	R$2,87	R$2,33	R$2,67	R$2,80	R$3,10	R$2,10	R$3,20	R$2,73	R$2,33	R$3,00	R$3,00

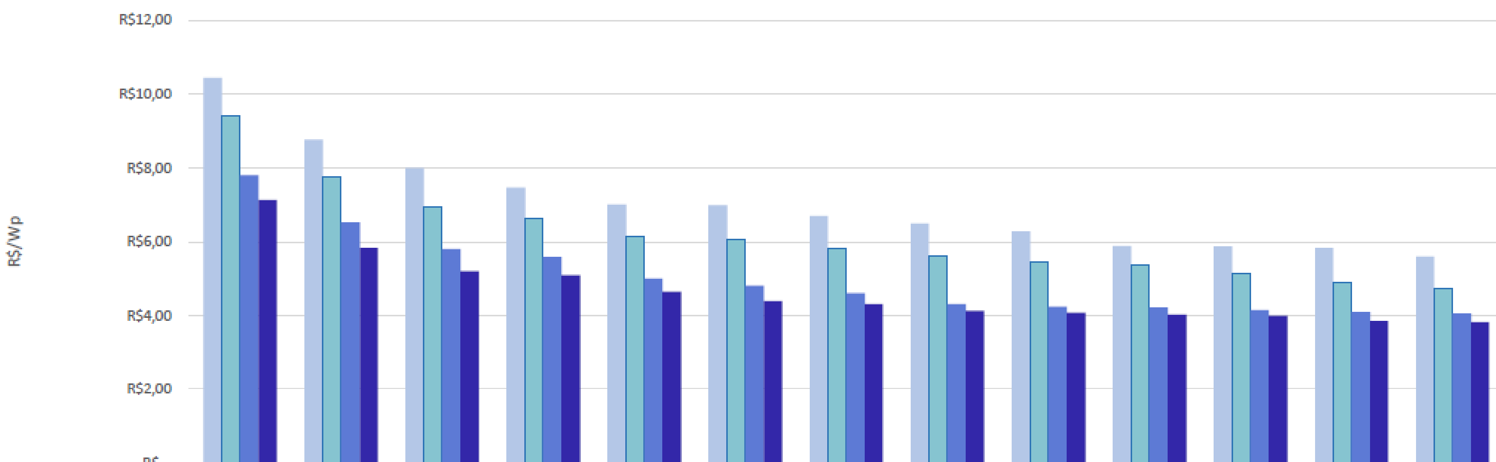
Figure 9 Solar system prices for the end customer in January 2018

(Source: (Greener, 2018a))

This figure 9 shows the price of solar system for the end customer in January 2018 by the capacity. The prices are categorized by the most expensive price, average maximum price, average price, average minimum price and the lowest price. In general, the lower capacity of solar panels is more expensive than the higher capacity one.

How dramatically the price has been decreasing last years by in comparison the price from June 2016 to January 2018 is shown on the next figure 10.

- Average Variation June / 2016 to January / 2018: -33.77%
- Average Variation January / 2017 to January / 2018: -24,04%
- Average Variation June / 2017 to January / 2018: -4.75%



	2 kWp	4 kWp	8 kWp	12 kWp	30 kWp	50 kWp	75 kWp	150 kWp	300 kWp	500 kWp	1 MWp	3 MWp	5 MWp
Preços Médios jun/2016	R$10,45	R$8,77	R$7,99	R$7,47	R$7,01	R$7,00	R$6,68	R$6,49	R$6,28	R$5,88	R$5,88	R$5,83	R$5,60
Preços Médios jan/2017	R$9,43	R$7,74	R$6,94	R$6,63	R$6,14	R$6,06	R$5,82	R$5,63	R$5,47	R$5,36	R$5,15	R$4,88	R$4,74
Preços Médios jun/2017	R$7,81	R$6,52	R$5,80	R$5,59	R$4,99	R$4,80	R$4,60	R$4,31	R$4,24	R$4,22	R$4,14	R$4,10	R$4,06
Preços Médios jan/2018	R$7,13	R$5,83	R$5,21	R$5,09	R$4,64	R$4,39	R$4,31	R$4,13	R$4,07	R$4,02	R$4,00	R$3,85	R$3,82

Figure 10 Prices for the end customer from June 2016 to January 2018

(Source: (Greener, 2018a))

	2014	2015	2016	2017
Commercial power	16.651 MWp/year	63.996 MWp/year	82.938 MWp/year	297.617 MWp/year
Acting companies	388	906	1500	2741
Average volume traded per company per year	42.91 kWp/year/company	70.64 kWp/year/company	55.29 kWp/year/company	108.58 kWp/year/company
Average volume traded per company per month	3.58 kWp/month/company	5.89 kWp/month/company	4.61 kWp/month/company	9.05 kWp/month/company

Table 5 Average business volume by company

(Source: (Greener, 2018a))

Not only the commercial power and the number of acting companies have amplified but also the average volume traded per company also has been increasing steadily and it number in 2017 rose up 96.31% compared to 2016 (Table 6).

In conclusion, the distributed generation photovoltaic market accelerated sharply in the second half of 2017 delivering an excellent result compared to the previous year. At the same time new challenges begin to appear, the market becomes more pulverized making room for regional suppliers. Even with a high cost of the equipment in the last six months due to the price increase of the photovoltaic modules, the price of the systems for the final customer continues to fall. This clearly reflects two situations: increased turnover for integrating companies providing economy of scale; a second aspect is linked to the greater number of companies in the market increasing competitiveness and reducing margins. Also, the market accelerated in volume and in competitors. There has been a significant increase in the number of integrating companies and many of them with mixed operations (energy efficiency for example) allowing them to work at tighter margins due to the reduction of their fixed expenses with other areas of activity of the company.

With the growth of the market, some companies started to import equipment directly. It is important to carefully evaluate the import, although it brings an apparent benefit in the cost of the photovoltaic kit, there are other costs inherent to the operation, such as working capital, inventory cost, inventory depreciation, inventory turnover, availability, logistics risks, etc. Financial cost is another important driver that has contributed a lot in recent months to customers who have been able to access lines of credit. The tendency is for credit availability to increase with the maintenance of lower interest rates. Few companies actually use lines of financing to increase their sales. The biggest bottleneck in this is not in relation to the bureaucracy for access to credit, but the lack of knowledge and preparation of the companies in presenting guarantees to the financing agents that the project in question has low risk, both with respect to the client and with relation to the supplier (the integrator / distributor / manufacturer itself) (Greener, 2018a).

Figure 11 Solar PV business map

(Source: America do SOL)

Additionally, the website ‘America do SOL’ offers information about local business about solar energy in Brazil (http://www.americadosol.org/fornecedores/) (Figure 11).

3.2. Energy policy analysis

Large hydropower remains the principal source of electricity supply, with other renewable energies representing about 10%. Wind, solar and small hydro (defined as less than 50 MW in Brazil) have increased their share of the energy mix since energy sector reforms in 2012 that were ratified under the government of Dilma Rousseff.

The new government of Michel Temer has proposed a new legal framework to modernize and liberalize the energy market to attract private investments. Among the proposed measures are: opening the market to new customers, the gradual ending of subsidies, maximizing the cohesion between energy prices and operations, introducing a capacity remuneration mechanism, and resolving judicial disputes related to hydrological risk for hydropower plants. Since Brazil is moving away from large hydropower projects in favour of decentralized renewable energy, there are only fewer major hydropower projects being prepared in the 10-year pipeline of the Ministry of Mining and Energy (International Hydropower Association, 2018).

3.2.1. Energy demand development

Demand elements such as income, population, and electricity tariff positively could affect the growth of PV units in Brazil. This is the reason why over half of PV units in Brazil are located in the Southeast Region, which is richer, more populated, and has a higher average tariff than other regions of Brazil.

3.2.2. National/state analysis

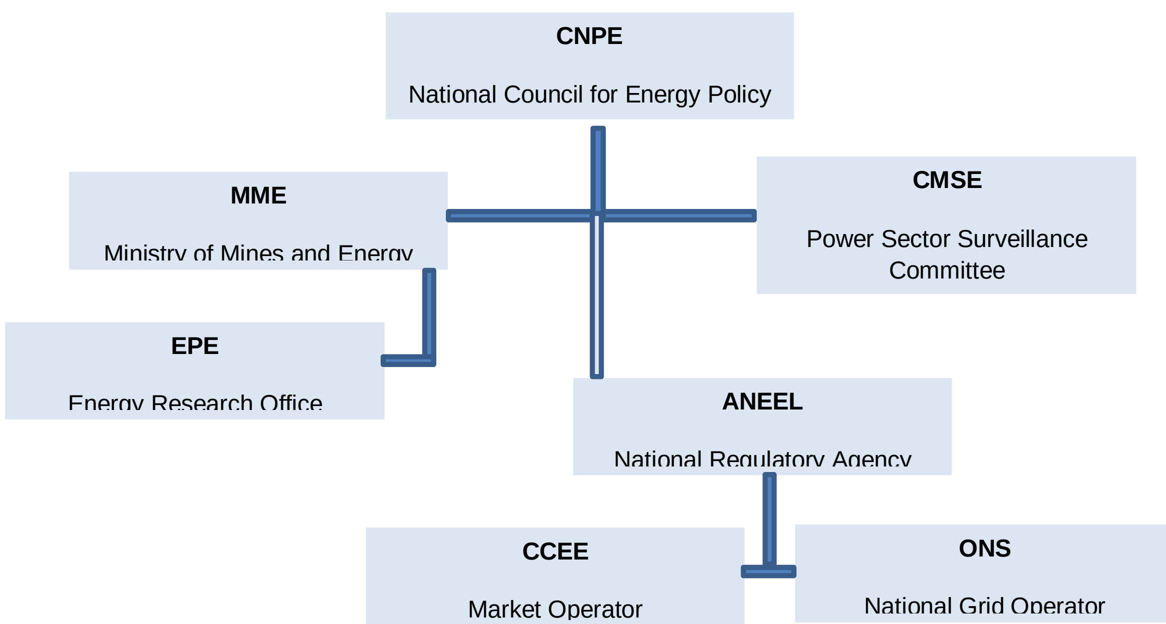


Figure 12 Energy governance structure

Figure 12 shows the energy governance structure of Brazil. Ministry of Mines and Energy (MME) and ANEEL are the main regulatory authorities. MME is responsible for formulating and implementing national policies on the energy sector. It is responsible for granting concessions and permissions to exploit electric power services and facilities. ANEEL is a special independent body connected to the MME. It has a role for technical and political autonomy to regulate, supervise and monitor activities related to the energy sector.

With regard to electricity generation, the first major initiative was developed in 2002, when the Alternative Energy Sources Incentive Program (Programa de Incentivo às Fontes Alternativas de Energia Eléctrica - PROINFA) was approved by Law No. 10,438. The program was implemented in 2004 with the objective of increasing the share of electricity produced by projects designed based on wind, biomass and small hydroelectric power plants in the National Interconnected Electric System. Note that solar energy was not included in the Program, because at that time it was still little disseminated its use. However, the Program reflects the Brazilian State's firm intention to incorporate other renewable energies distinct from the large hydroelectric plants within the national energy matrix.

The most vital determination for the development of Brazil’s solar approach was the recent enactment of new rules by ANEEL targeted at dropping obstacles for the incorporation of distributed solar power.

In April 2012, ANEEL issued **Resolution 482/2012**, establishing the general conditions for the access of microgeneration to the electric energy distribution systems, and the electric energy compensation system. The compensation system is defined as an arrangement in which the active energy injected by consumer units with distributed generation is transferred to the local distributor. The consumer is then subsequently compensated through their consumption of active electricity. In the net metering system, electricity consumer installs small generators in their consumer unit and the generated energy is used to reduce the electricity consumption of the consumer (Juliano Assunção and Amanda Schutze, 2107).

In other words, it made possible to send excess power from distributed generation to the Brazilian grid, with the final consumer being rewarded later in the form of credits (discounts) in future bills. However, there is a strong vulnerable point of this system. With the current net metering system, the government imposes taxes people for all electricity consumption, in spite of whether they produce their own electricity. For example, if a client generates 300 kWh from their own solar panel and consumes another 700 kWh from the grid, this person should pay the tax on the full 1,000 kWh, even though the client uses his own electricity and contributed not to use the conventional electricity. Professor Amaro Pereira from Universidade Federal do Rio de Janeiro mentioned on the interview with me that it is worthy to think why Brazilian government adopted this net metering credit system. He assumed that if it is allowed to “sell” the electricity to the utility company, this would be only possible for middle class at least and the low class like favelas would be completely excluded since they cannot join to this market. Therefore, he mentioned that the society gap could be considered before initiating this policy.

To encourage the advancement of the sector, in 2015 the government exempted PIS / PASEP and COFINS on distributed generation. In the same year, the ICMS Convention 16/15 was instituted by the National Finance Policy Council, authorizing states to exempt consumers from paying the tax on the value of the energy they consume from the distributor if it corresponds to the number of energy credits they obtained through the net metering system. In other words, the consumer will only be charged the ICMS on the electric power that exceeds the amount previously injected by the unit on the distribution system (Juliano Assunção and Amanda Schutze, 2107). Until today, 21 states have joined the proposal, with Rio de Janeiro being one of them. This measure is very important to improve the financial viability of the distributed solar generation, since it supposes the saving of a tribute that weighs in the electricity bill. The ICMS is a state tax whose rate fluctuates in the range of 0% - 32% in the case of Rio de Janeiro.

In November 2015, through **Resolution 687/2015**, some items were adjusted to further promote the development of the sector. In these resolutions, it was defined that it will be considered as distributed ‘micro’ power generation plants with power ‘up to 75 kW’, using renewable sources or qualified cogeneration. However, those plants with a power of between ‘75 kW and 3 MW’ will be considered as distributed ‘mini’ power generation. In the end of 2017, this maximum capacity of mini power generation increased up to ‘5 MW’.

Additionally, through Resolution 687/2015, it was established how the system of compensation of electric energy works, yielding the active energy generated by the consumer unit through a free loan to the local distributor and later compensating within a period of ‘60 months’ with the energy consumption. This point also applies to members of enterprises of multiple consumer units or characterized as remote self-consumption.

Through Resolution 649/2015, the energy bills started to bring a new system in 2015 -Tariff Flag System (Figure 13). The color of the flag that is printed on the light bill (green, yellow or red) indicates the cost of energy, depending on the conditions of electricity generation. In this way, it is necessary to recover the extra expenses with the use of energy from thermoelectric power plants, which is more expensive than hydroelectric power plants. When it rains less, for example, the reservoirs of the hydroelectric dams become emptier and it is necessary to activate more thermoelectric to guarantee the energy supply in the country.

- Green flag: favorable conditions of power generation. The fare does not suffer any increase.
- Yellow flag: less favorable generation conditions. The tariff is increased by $ 1 real for each 100 kWh consumed.
- Red flag - Tier 1: more expensive generation conditions. A surcharge of R$ 3 for each 100 kWh consumed.
- Red Flag - Tier 2: even more expensive conditions of generation. The tariff is increased by R$ 5 for each 100 kWh consumed.

Figure 13 Category and example of tariff flag system

(Source: (Light))

Besides the economic aspect, this system has an educational character, since it makes the consumer aware of the reality of the country to generate energy so that they try to reduce its consumption to avoid the high tariff as well. ANEEL announces each month which flag color will be applied in the following month, and in this way the consumer will know in advance if they should pay any additional extra for the energy they consume. The values of the tariff flags are revised each year, according to the variations of energy cost.

In 2017, BNDES' local content requirement (LCR) rules mandate that solar modules be assembled in Brazil, but cells and other equipment can be imported. As Brazil does not currently have a complete solar supply chain in country, imports will be required (Export.gov, 2017).

3.2.3. Subsidy – FIT (Feed in Tariff)

Auctions for feed-in tariffs promoted by the Brazilian government usually grant benefits to renewable sources, especially wind and solar. Projects based on solar, wind or biomass energy are entitled to a reduction of at least 50% when using the transmission or distribution systems provided that:

- The power supplied to the transmission or distribution systems exceeds 30,000 kW and is equal to or less than 300,000 kW.
- The project results from auctions held before 1 January 2016.

ANEEL has approved a further discount of 80% for solar plants that begin operations by 31 December 2017, with a reduction to 50% after the tenth year of operation (Practical Law, 2018).

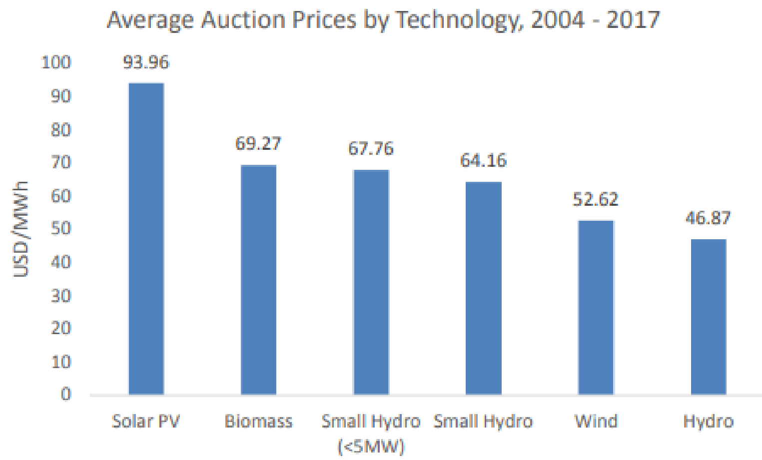


Figure 14 Average Auction Prices by Technology, 2004 – 2017

Source: (Hochberg & Poudineh, 2018)

From December 2004 to April 2017, Brazil held 74 electric generation auctions, resulting in more than 8,700,000 GWh of electric generation capability and 488 billion USD in investment. Under the auctions, renewable electricity prices have decreased considerably. Moreover, additional renewable technologies have been deployed through auctions as well (Hochberg & Poudineh, 2018) (Figure 14).

Technology	Auction "A-4" – USD/MWh	Auction "A-6" – USD/MWh
Hydro	$55.1	$66.5
Biomass	$71.27	$65.78
Wind	$32.76	$29.92
Solar PV	$44.19	N/A
Natural Gas Thermal	N/A	$64.76
Auction Average	$43.84	$57.5

Figure 15 Pricing from Brazil's December 2017 long-term electricity auctions

Source: (Hochberg & Poudineh, 2018)

Brazil's most recent auctions were held in December 2017 (Figure 15). The auctions, A-4 and A-6, require corresponding commercial operation dates for 2021 and 2023, respectively. Both were multi-technology auctions, while A-4 was exclusively for renewables and A-6 included renewables competing directly with natural gas. The outcome for A-4 is expected to result in additional installed capacity of 674.5 MW, of which around 85 percent will be solar PV. Auction A-6 resulted in 2,736.6 of new capacity, most of which will come from natural gas and wind (Hochberg & Poudineh, 2018).

3.2.4. Electricity prices

In Brazil, the public electricity distribution service is working by 63 concessionaires and 38 permissionaires. Distributors are not allowed to fix their own costs since they are controlled by the government through ANEEL.

Between the decades of 1970 and 90, there was a standardized bill for all the states in Brazil. Lately, it was verified that this was not fair to all the locations, because the costs of transmission and distribution were different according to the place where the energy had to be taken. Nowadays, the price of electric energy in Brazil is calculated taking into account three different costs:

- energy generation
- transportation of the energy to the houses: transmission and distribution
- taxes

Regarding taxes, there are federal, state and local taxes included in the electric bill (Ana Gabriela Verotti Farah, 2013).

Federal taxes

PIS (Programa de Integração Social - Social Integration Program) / COFINS (Contribuição para o Financiamento da Seguridade Social - Contribution for Social Security Financing)

COFINS has two different aliquots: 7% - for the goods that goes from São Paulo, Rio de Janeiro, Minas Gerais, Paraná, Santa Catarina and Rio Grande do Sul to the other parts of the country - and 12% - in general

State taxes

ICMS (Imposto Sobre a Circulação de Mercadorias e Serviços - Tax on Circulation of Goods and Services)

: Operations involving equipment which is used in the generation of wind and solar energy can possibly be ICMS tax exempt until 31 December 2021

Local taxes

CIP or COSIP (Contribution for the Cost of Public Lighting)

$$Electricity\ Tariff = \left\{\frac{Regulated\ Tariff\ by\ ANEEL}{1-(PIS+COFINS+ICMS)}\right\} + CIP$$

Other taxes

CCC (Fuel Consumption Account)

ECE (Emergency Capacity Charge);

RGR (Global Reservation of Reversion)

TFSEE (Electric Energy Services Supervisory Tax)

CDE (Energetic Development Account)

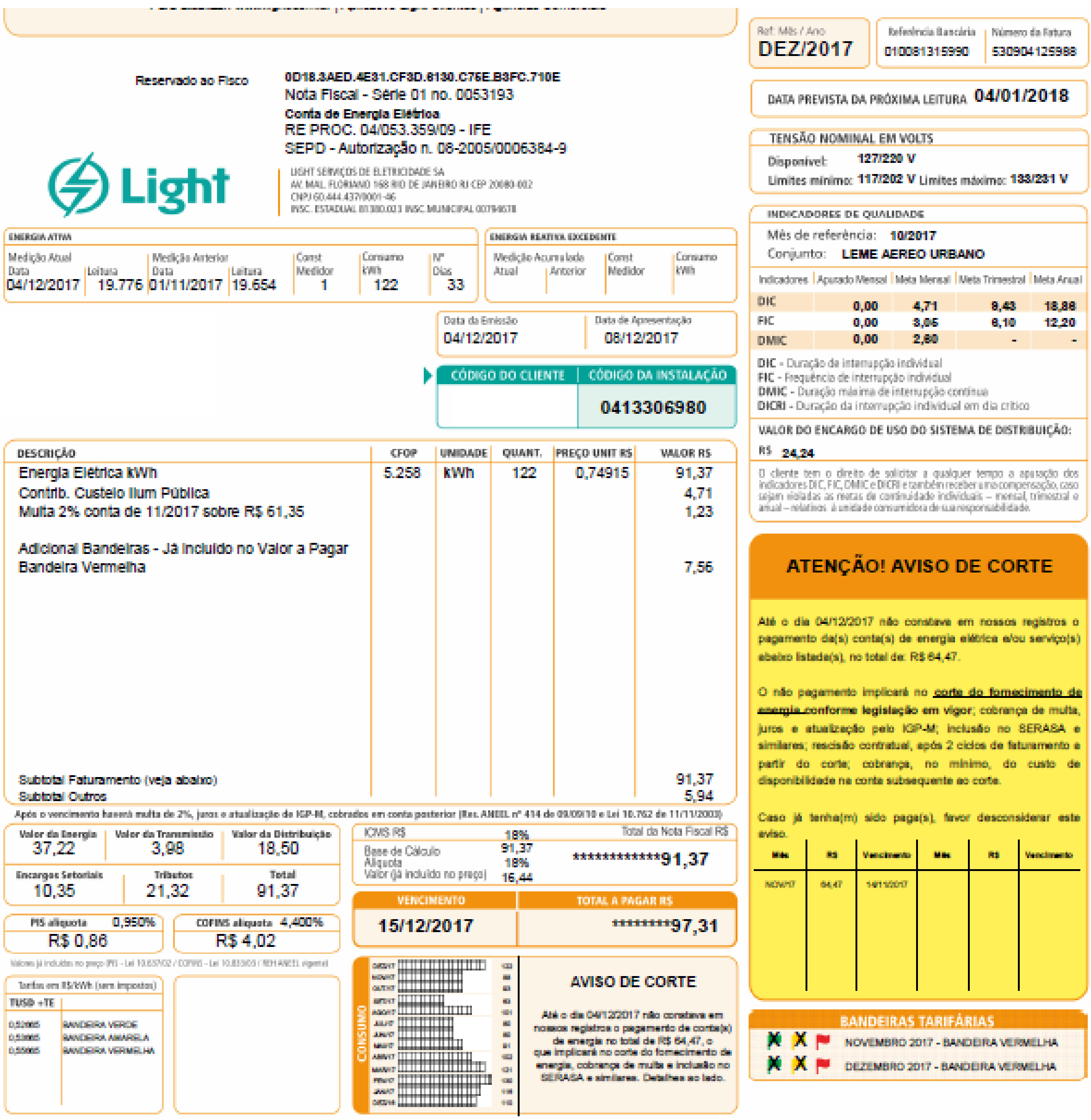
ESS (System Service Charges)

R & D (Research and Development and Energetic Efficiency)

ONS (National System Operator)

CFURH (Financial compensation for the use of water resources)

The taxes included in the bill of Light are the Federal taxes (PIS and COFINS) and the State tax (ICMS). Figure 16 is the example of the electricity bill of a household in Babilônia on December 2017.



Ref: Mês / Ano: DEZ/2017 | Referência Bancária: 010081315990 | Número da Fatura: 530904125988

Reservado ao Fisco: 0D18.3AED.4E31.CF3D.8130.C76E.B3FC.710E
Nota Fiscal - Série 01 no. 0053193
Conta de Energia Elétrica
RE PROC. 04/053.359/09 - IFE
SEPD - Autorização n. 08-2005/0006384-9

Light

DATA PREVISTA DA PRÓXIMA LEITURA 04/01/2018

TENSÃO NOMINAL EM VOLTS
Disponível: 127/220 V
Limites mínimo: 117/202 V Limites máximo: 133/231 V

ENERGIA ATIVA

Medição Atual Data	Leitura	Medição Anterior Data	Leitura	Const Medidor	Consumo kWh	Nº Dias
04/12/2017	19.776	01/11/2017	19.654	1	122	33

ENERGIA REATIVA EXCEDENTE

Medição Acumulada Atual	Anterior	Const Medidor	Consumo kWh

Data da Emissão: 04/12/2017 | Data de Apresentação: 08/12/2017

CÓDIGO DO CLIENTE | CÓDIGO DA INSTALAÇÃO: 0413306980

INDICADORES DE QUALIDADE
Mês de referência: 10/2017
Conjunto: LEME AEREO URBANO

Indicadores	Apurado Mensal	Meta Mensal	Meta Trimestral	Meta Anual
DIC	0,00	4,71	9,43	18,86
FIC	0,00	3,05	6,10	12,20
DMIC	0,00	2,60	-	-

DIC - Duração de interrupção individual
FIC - Frequência de interrupção individual
DMIC - Duração máxima de interrupção contínua
DICRI - Duração da interrupção individual em dia crítico

VALOR DO ENCARGO DE USO DO SISTEMA DE DISTRIBUIÇÃO: R$ 24,24

DESCRIÇÃO	CFOP	UNIDADE	QUANT.	PREÇO UNIT R$	VALOR R$
Energia Elétrica kWh	5.258	kWh	122	0,74915	91,37
Contrib. Custeio Ilum Pública					4,71
Multa 2% conta de 11/2017 sobre R$ 61,35					1,23
Adicional Bandeiras - Já incluído no Valor a Pagar					
Bandeira Vermelha					7,56
Subtotal Faturamento (veja abaixo)					91,37
Subtotal Outros					5,94

Valor da Energia	Valor da Transmissão	Valor da Distribuição
37,22	3,98	18,50
Encargos Setoriais	**Tributos**	**Total**
10,35	21,32	91,37

PIS alíquota 0,950%: R$ 0,86 | COFINS alíquota 4,400%: R$ 4,02

ICMS R$: Base de Cálculo 91,37; Alíquota 18%; Valor (já incluído no preço) 16,44
Total da Nota Fiscal R$: ************91,37

VENCIMENTO: 15/12/2017 | TOTAL A PAGAR R$: ********97,31

ATENÇÃO! AVISO DE CORTE

Até o dia 04/12/2017 não constava em nossos registros o pagamento da(s) conta(s) de energia elétrica e/ou serviço(s) abaixo listada(s), no total de: R$ 64,47.

O não pagamento implicará no corte do fornecimento de energia conforme legislação em vigor; cobrança de multa, juros e atualização pelo IGP-M; inclusão no SERASA e similares; rescisão contratual, após 2 ciclos de faturamento a partir do corte; cobrança, no mínimo, do custo de disponibilidade na conta subsequente ao corte.

Caso já tenha(m) sido paga(s), favor desconsiderar este aviso.

Mês	R$	Vencimento	Mês	R$	Vencimento
NOV/17	64,47	14/11/2017			

AVISO DE CORTE

Até o dia 04/12/2017 não constava em nossos registros o pagamento de conta(s) de energia no total de R$ 64,47, o que implicará no corte do fornecimento de energia, cobrança de multa e inclusão no SERASA e similares. Detalhes ao lado.

Tarifas em R$/kWh (sem impostos)
TUSD + TE
0,52065 BANDEIRA VERDE
0,53065 BANDEIRA AMARELA
0,55065 BANDEIRA VERMELHA

BANDEIRAS TARIFÁRIAS
NOVEMBRO 2017 - BANDEIRA VERMELHA
DEZEMBRO 2017 - BANDEIRA VERMELHA

Figure 16 An example of electricity bill of Light (December, 2017)

TARIFAS DE BAIXA TENSÃO - R$/kWh - Agosto/2018							
Classe de consumo	Tarifa com PIS/COFINS e ICMS					Tarifa homologada pela ANEEL sem incidência de ICMS/PIS/ COFINS	Tarifa com PIS/COFINS isenta de ICMS
	Faixa consumo						
	até 50 kWh	de 51 até 300 kWh	até 300 kWh	de 301 até 450 kWh	acima de 450 kWh		
	Residencial	Residencial	Demais Classes	Todas as Classes	Todas as Classes		
	(isento de ICMS)	(ICMS de 18%)	(ICMS de 20%)	(ICMS de 31%)	(ICMS de 32%)		
Residencial	0,60812	0,75112	-	0,90477	0,91923	0,57498	0,60812
Tarifa Social							
· até 30 kWh	0,19681	0,24308	-	0,29281	0,29749	0,18608	0,19681
· 31 até 50 kWh	0,33738	0,41672	-	0,50196	0,50999	0,31900	0,33738
· 51 até 100 kWh	-		-				
· 101 até 220 kWh	-	0,62507	-	0,75294	0,76498	0,47849	0,50608
· acima de 220 kWh	-	0,69453	-	0,83660	0,84998	0,53166	0,56231
Não residencial	-	-	0,77127	0,90477	0,91923	0,57498	0,60812
Rural	-	-	0,53989	0,63334	0,64347	0,40249	0,42569
Iluminação Pública							
· Rede de Distribuição	-	-	0,42420	0,49762	0,50558	0,31624	0,33447
· Bulbo da Lâmpada	-	-	0,46278	0,54288	0,55156	0,34500	0,36489

Table 6 Electricity tariff by Light in August 2018

(Source: Light)

Table 7 shows the electricity tariff by Light in August 2018. TSEE (Tarifa Social de Energia Elétrica) is a discount granted by the Federal Government in the electric energy tariff created by law 10.438/02 to be granted to families that meet the criteria established in Law 12.212/10. The discount can vary from 10% to 65%, as follows (Light):

- First 30 kWh / month consumed = 68% discount
- Consumption above 30 kWh up to 50 kWh / month = 45% discount
- Consumption above 50 kWh up to 100 kWh / month = NO discount
- Consumption above 100 kWh up to 220 kWh / month = NO discount
- Consumption above 220 kWh = NO discount

The entitled people to the social tariff are as follows.

- Family enrolled in the Single Registry for Social Programs (Cadastro Único para Programas Sociais) of the Federal Government, with monthly family income per capita less than or equal to half a national minimum wage.

- Person who receives the Benefit of Continuous Rendering of Social Assistance (Benefício de Prestação Continuada da Assistência Social).
- Family enrolled in the Single Registry with monthly income of up to three minimum wages, which has a disease or disability, whose treatment or medical procedure requires the continued use of equipment that depends on the consumption of electric energy.

Currently, it seems like the social tariff doesn't work properly. There was a time that Light was concerned about the social tariff and social responsibility. However, the direction changed now and the price has been skyrocketing even with the social tariff. Light has to talk with the government to tackle the problem. If the tariff keeps high, low income class cannot afford and it is crucial for everyone. In addition, to be allowed as a social tariff, it has become very restricted and it is difficult to register for the system of Light. Compared to four years ago, more people are excluded now. But even after being registered as a social tariff household, their consumption should be limited because even though they pay less than the full price, they cannot exceed certain amount of electricity. Consuming over 50 kWh/per month is excluded for the discount, however living with this amount of electricity is also not very easy even for residence in favelas. It means that they are still poor with consuming in this context.

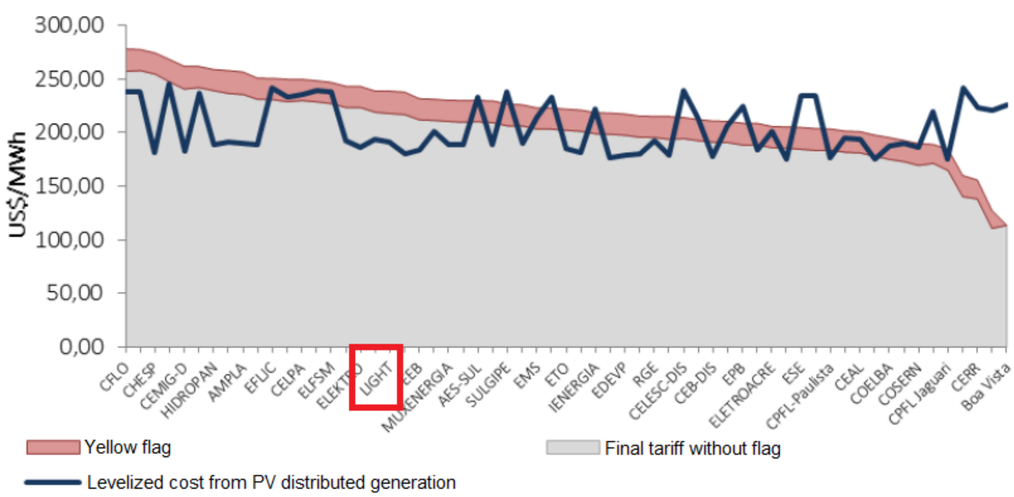


Figure 17 Electricity tariff versus cost of distributed photovoltaic generation.

(Source: (EPE, 2016))

Additionally, figure 17 presents the comparison of electricity tariff and cost of distributed PV generation about the power suppliers in Brazil. In the case of Light, the levelized cost from PV is already lower than the final tariff without applying the flag system. Therefore, the gaps become bigger when the flag is applied in summer.

3.3. Electricity issues in Favelas

3.3.1. Electricity efficiency

Ehrhardt-Martinez has argued that in comparison with the more traditional sources of energy such as wood and coal (whose quantities the consumer can see), electricity is an invisible resource. This fact makes it difficult for consumers to estimate the amount they are consuming (Karen Ehrhardt-Martinez, 2011).

To provide convenience and reduce residential electricity costs in the real-time or multi-tariff system, it is required to investigate the load/consumption patterns, customer behaviour and behavioural predictability to develop optimal control methods, which take into account customer habits and load differences (Argo Rosin, Taavi Möller, Madis Lehtla, Hardi Hõimoja, 2010).

Since Light started to have access to favelas, they tried various electricity efficiency programs in order to solve the illegal electricity use issue and to educate residents how to save electricity. For example, electrical appliances such as refrigerators and lamps were changed to the higher efficiency products for free as most of them were very old and consumed lots of electricity. Some of programs brought a good result by improving the efficiency in favelas, however, it also has a few problems to carry forward the program. In fact, some people suspect that dwellers who received the high efficiency appliances could sell them back to the black market.

Light also modernized old utility pole and wires (Figure 18), however, some people tried to steal it by taking the risk. The new equipment has been stolen as well. In addition, they hand over money to the technicians from Light to try to install extra equipment to steal electricity. Also, residents who steal the electricity would not pay the bill so do not feel the reason to try to save electricity in a more efficient way. If we think that my neighbor steals the electricity and don't pay money, we would also think why we should pay. Therefore, there is a strong connection between the illegal electricity use and energy efficiency issue and it is very difficult to change the perception of people. Especially, with the increased violence of Rio de Janeiro, the informality situation becomes worse. Moreover, since the economic crisis lasts for a long time, Light also has been trying to decrease the budget for social responsibility and sustainability which are related to the energy efficiency program.

Figure 18 Refrigerators in a bakery and modernized equipment in Babilônia

(Photo: own photograph)

'Light Recycle' is a sustainable project to exchange recyclable waste for points in the electricity bill. Participants register with Light's eco-points and receive the customer's card and deliver recyclable materials such as plastic, metal, glass, paper and vegetable oil in exchange for these points. Each item has a price by weight that generates the point. Currently, Light has 10 Light Recycle offices in Rio de Janeiro to assist registered customers (Figure 19, 20).

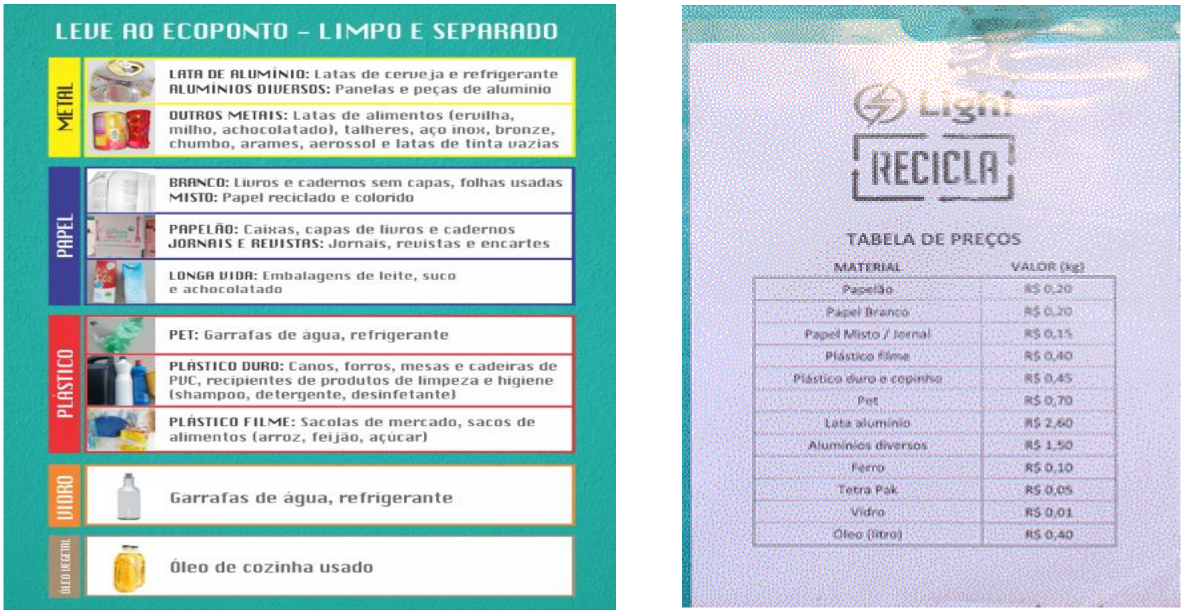


Figure 19 Light Recycle – Eco point and its tariff in May, 2018

(Source: Light and own photograph)

Figure 20 Light Recycle office in Babilônia and eco point card

(Photo: own photograph)

In conclusion, it is important to emphasize the need to develop policies and programs to raise awareness of all the benefits, rights, and duties of consumers who are accustomed to illegal connections. On the one hand, the company is committed to providing good-quality service, by making investments in networks, transformers, meters, and other items in the communities. On the other hand, the consumers in favela communities need to consider the distribution of electricity as a legal product and fit it into their budget (Ribas & da Silva Rocha, 2015).

3.3.2. Electricity theft

The state of Rio de Janeiro has one of the highest commercial loss of electricity suppliers by the illegal electricity use. It is assumed that approximately four million customers of Light try this and it is estimated that 460,000 are located in favelas. These areas account for some 40% of so-called 'non-technical' losses because of theft of electricity (Ribas & da Silva Rocha, 2015). A probable reason why Light cannot suspend the power supply to those areas with the illegal electricity use although Light makes lots of loss is because Light is a public company and electricity is a type of public service. From the interview with Paulo Senra, a former worker at Light, I could check that Light proves the commercial loss by the illegal electricity use to ANEEL and compensates the loss by applying a tariff. It means that if there is no illegal electricity use, the tariff for end consumers could decrease up to 17%. The illegal electricity use occurs in various parts of the city but the percentage is different in each part. In some area, 80% of electricity are consumed illegally but some area only has 0.5% of illegal electricity use.

On the other hand, there are opinions that it is frustrating for dwellers in favelas that people think everyone in favela steals their electricity although some has paid the electricity bill appropriately the whole life. Additionally, UPP program has made notable progress in improving security in favelas and therefore the illegal electricity use has been decreasing a lot. Despite of it, there is also concern about the secondary effects. Many communities having UPP with better public security started to bring more new resident and this tendency increased the rents for houses in these areas.

Based on the strong social and political complex, dwellers in favelas have deep distrust with the government. Likewise, Light is a state company so they might consider that the government should supply the electricity for free. It is also a distrust and perception issue between every stakeholder.

In this connection, there are also opinions that Light treats people from Favela in different ways. On the interview with Professor Claude Cohen from Universidade Federal Fluminense, she also pointed out this situation and the reason is because Light might think that the low class client does not pay the bill. Therefore, when something doesn't work properly related electricity, it takes a few days to go to fix it to favelas, whereas it would be fixed in some hours for middle class.

3.3.3. Social participation in favelas

Community involvements in project design and implementation is critical for developing a sense of ownership and for its ultimate sustainability. Building local capacity for self-organization and social participation was an integral part of the program's methodology. From the outset in each area, community associations were consulted and involved in the design process. Also, transparency and efficiency are key aspects in adequate implementation (Jose Brakarz and Wanda Engel Aduan, 2004).

Some strategies for community participation include:

• Involving the community in the decision-making process of the project from its inception until its completion. Community consultation and participation is helpful in defining project solutions, selecting social services and determining the location of facilities, deciding on resettlement options and helping with the process.

• Organizing neighborhood associations and using them as channel for communicating with the rest of the community.

• Employing neighborhood associations to provide services.

In the case of Rio de Janeiro, it is interesting to identify the benefits and costs of using Community participation into the development planning and project management. A rapport from the World Bank on Community participation, states the reasons why development planners and managers should be concerned to ensure that local communities are consulted and involved from the beginning of the project. The reasons are stated below (World Bank, 1986).

• Design of the project is improved because of the knowledge of the local community on local technologies, customs and area (topography, climate).

• Ensure the social project acceptability.

• Ensure equitable distribution of benefits for the whole community.

• Helps the resources mobilization.

• Community institution developed during project implementation will continue to produce further benefits once the project is completed.

It is very essential that the residents feel by themselves they are part of the society which they belong in order to implement a project which needs their participation. However, they are often excluded by decision making process of projects and do not have access to receive the updated information.

On the one hand, with the distinct social characteristics, dwellers in favelas have a strong bond and solidarity each other. Many of them live in a community for a long time and have a big family. It makes them have a very close identity between their neighbors. This characteristic of favelas is an important part in consideration of the difficultness to implement a project in a community which is usually in the edge of the society.

4. CASE STUDY – BABILÔNIA

4.1. General information

The project site Babilônia Community is located close to the Copacabana beach facing the Atlantic Ocean and another favela called Chapéu Mangueira is located just next to Babilônia as a neighborhood (Figure 21). Both favelas have more than 100 years of existence in this area and Babilônia occupied total 85,956 m² of area in 2017 (SABREN, 2016). Babilônia occupies an area considered strategic by Rio de Janeiro, given the social, cultural, political and economic tensions that contrast the ways of life of slum dwellers and the inhabitants of Leme. The reason is that Babilônia is situated in Leme which is a fancy area of the city near the beach with many touristic facilities and this area is defined as ‘asfalto’ in Portuguese (Map 6, 7).

According to the census of the population by IBGE in 2010, the total population was 2,451 and the total household was 777 in Babilônia. Also, 1,288 people and 401 households were registered in Chapéu Mangueira (SABREN, 2016). However, residents of the community say that there are approximately 6,000 people who live in Morro do Leme.

Figure 21 Photo of Babilônia

(Source: Revolusolar)

Map 5 Location of Babilônia and Chapéu Mangueira (1)

(Source: SABREN)

Map 6 Location of Babilônia (left) and Chapéu Mangueira (right) (2)

(Source: SABREN)

4.2. Social analysis of Babilônia

According to the book ‘Um País Chamado Favela (A country named Favela)’ published in 2014 by Renato Meirelles, the average monthly income was R$ 965. Therefore, with the high inflation, it is possible to assume that it hovers slightly over R$ 1,000 which are about 260 USD.

In Meirelles' evaluation, it is mentioned that the favelas in Rio de Janeiro are close to the southern zone, the region's highest income area. As a result, the favela population find jobs with better wages compared to favelas in the other area. Babilônia is also an example of this situation. Due to the perfect location near the Leme beach, many of dwellers work for tourists formally like in restaurants and hotels or informally selling food or stuff and lending products on the beach.

In 2009, with the arrival of UPP in Babilônia, the government of Rio de Janeiro promised the access to better public service for residents: education, water, sanitation, energy quality and the restructuring of a proximity between the State and residents. Babilônia was within the scope of the social program ‘Morar Carioca’ which aims to urbanize favelas in Rio de Janeiro until 2020 due to the mega international events - 2014 Olympic Games in Rio de Janeiro and 2014 World Cup in Brazil.

As Babilônia was within the set of areas that have been impacted by the program ‘Morar Carioca’ works, residents anticipated the integration of the favela and the city but also envisaged infrastructure works (opening of roads, sewage and basic sanitation, etc.). Everyone had hope that the program would regularize or broaden the quality of public services needed by the community, such as garbage collection, water and, above all, electric energy. However, what is verified is that the execution of a project which has been presenting from its foundational had deep discrepancies between practice and governmental proposal. Such notes become more visible if we observe what the residents of Babilônia insist about the consumption of electric energy in the community.

4.3. Public security situation in Babilônia

UPP is a law enforcement and social services program established in the state of Rio de Janeiro, which targets generally favelas where practically ruled by gangs of drug suppliers. The first UPP was organized in Dona Marta in 2008 and then later other favelas in Rio also started to have UPP. Babilônia was the fourth UPP implemented in 10 June 2009 (Figure 22). For a long time, Rio has been struggling with the violence between drug traffickers and police and residents had no option not to be suffered by this risk. Consequently, the idea for the UPP was lastly proceed as an initial step key to manage the everlasting violence. Commonly, the violent crime of favelas having the UPP has dropped rapidly, while bringing more incomes and new visitors into favelas.

In the case of Babilônia, the public security has achieved great progress since the implementation of UPP as well in the beginning. With the pacification, more and more people have entered as a resident and a tourist. A few hostels started their business to attract foreigners. Due to the great location having a mountain at the back and beach, it was an opportunity for residents of Babilônia. However, with the economic crisis of Rio de Janeiro, the public security turned to worsen in recent years.

Figure 22 UPP in Babilônia

(Photo: own photograph)

4.4. Risks of implementing a solar PV project in Babilônia

Before commence a project, it is necessary to revise the possible related risks. For this project, we can consider four categories of risks.

- Natural disaster risk: Rio de Janeiro was the municipality with the highest rainfall, with 107.7 mm of record in the South Zone. Heavy rain and landslide could impact the safety of solar PV. However, landslides haven't happened in recent years in Babilônia so that I will not consider this risk for the analysis.
- Economic crisis risk: Due to the economic crisis of Rio de Janeiro and also the chronic poverty in favelas, it is mandatory to take account of the economic situation of residents. In this analysis, I will use the concept 'cooperative' which residents participate with their budget as well, therefore the economic viability is one of the key points of the project.
- Maintenance risk: After installing the solar panels, maintaining them is crucial as well. Possible risks related the maintenance could be stealing and breaking panels. In respect of stealing panels, I will not consider this part owing to the fact that stealing itself is not a common crime in Babilônia and solar panels which were implemented in the community haven't have this problem. On the other hand, breaking panels by the product malfunction or shooting by lost bullets from gangs should be revised as a security fund.
- Architectural characteristic of buildings: Generally, favelas can be categorized in two types - in hill or in flatland. Favelas in flatland mostly have flat rooftops so that they can have more insolation. On the other hand, favelas in hill like Babilônia are inclined and have shadows from other buildings so that this causes less insolation. In addition, according to the interview with Professor Susanne Hoffman from Universidade Federal do Rio de Janeiro, she mentioned that dwellers in favelas usually use the rooftop for other purpose such as putting water tubes which are bigger than in conventional buildings. Also, many of them use this area for their small business. Therefore, it is usually difficult to utilize the rooftop 100% for implementing PV in favelas and we have to consider how much space is available for the project.

In addition, as mentioned above, a local NGO 'Revolusolar' founded by a Belgian entrepreneur Pol Dhuyvetter in 2016 is working for solar PV projects. Revolusolar is a new non-profit association whose objective is to reduce energy costs in the community through solar energy, considering that electricity prices in Rio de Janeiro almost have doubled in recent years (R$ 0.48 kWh in January 2014 to R $0.90 kWh in January 2016). So far, Revolusolar has been working with the funding from different stakeholders not only Brazilian institutions but also international ones. Currently, they are planning to implement a solar PVs in a local school 'Escolinha Tia Percilia' in Babilônia and has carried out various capacity programs to educate residents to learn electricity knowledge to be able to find a related job in the future (Figure 23).

Figure 23 Solar PV implemented in a hostel in Babilônia (1st pic) and

capacity program for residents in Babilônia by Revolusolar in March (2, 3, 4 pics), 2018

(Source: own photograph)

Map 7 Solar map in Rio de Janeiro

(Source: Mapa Solar do Rio de Janeiro)

Additionally, the website 'Mapa Solar do Rio de Janeiro (http://pcrj.maps.arcgis.com)' (Map 8) was made by EPE, the municipal government of Rio de Janeiro, GIZ to inform the potential of solar energy by the address. You can type the exact address or name of location and the result provides information of the state of solar potential, the average potential of solar PV per day (kWh/m²) and the roof area (m²). However, as shown on the map 8, the information about favelas are omitted from the map. The reason was related to the public security issue in favelas since it is not easy for researchers to enter each building of favelas. In the case of Babilônia, there are only a few information about areas near the street Ladeira Ari Barroso, which is the principal to enter Babilônia.

5. SURVEY ANALYSIS - ELECTRICITY DEMAND AND CONSUMPTION BEHAVIOUR IN BABILÔNIA

The sources of household energy consumption can be classified into heating and cooling, cooking, hot-water supply, and lighting and electric appliances (Shushi Sugiura, Ayaka Miwa, Tomoko Uno, 2013). The list below shows alternatives which residents in favelas think to guarantee the reduction of the expenses with electricity:

• To replacement of lamps by LED;

• To leave the appliance switched off or out of the socket;

• To turn off the lights in living rooms where no one is using;

• To avoid ironing and microwave;

• Not to switch on the electric shower;

• To reduce the use of the washing machine.

• To avoid spending too much time at home;

• To deliver recyclables to get rebates in the account via Recycle Light;

• To make complaints at Light;

According to the record of interview that Revolusolar had with the residents in Babilônia, a very small number of residents showed concern about not knowing what to do to reduce expenses. Some resident said that they did not change anything in the routine because they have almost nothing at home, nor do they have a washing machine.

The used strategies and calculations by residents to reduce energy spending reveal that the inhabitants of Babilônia are gradually internalizing the appeal made by social sectors concerned with the environment and propagating "energy reeducation" or "environmental reeducation". The discourse on reeducation was taken more seriously by Brazilian society as national events such as the rationing of 2001 and the blackout in November 2009 in several states of the country pointed to a crisis in the sector of electricity supply.

Thus, the discussion of environmental reeducation is well-known that the inhabitants of Babilônia understand what the elements of the house and the daily habits are able to raise their energy consumption. However, there are still many issues that involve the consumer process that is not sharp for users. One of the distorted phenomenon is that residents end up getting rid of the appliances to reduce the electricity consumption.

The idea of retiring some appliances obliges the resident to abdicate certain lifestyles that are completely contrary to the pattern of consumption that the Federal Government stimulated in the last years (2003-2016) when injected into the popular strata of the Brazilian social stratum the stimulus to increase of credit to the individual, enabling the acquisition of goods, mainly appliances, via credit card. The contradiction between having an appliance and not being able to use it or having to use it in a contained way perpetuates a negative image that the consumer (user) has the utility.

It is perceptible that the residents elaborate many hypotheses to justify the reason of the increase of price in the bills of energy, among them are:

• The clock is ticking wrong;

• The flags tariff is manipulated by the government;

• The regularization of Light;

• The economic crisis faced in the country made Light and other basic essential items (food, water, rent) increased;

• The electricity is "stolen" by Light;

• The illegal electricity use in the community raises the price for those who do not use the electricity illegally;

• The change in the way of measuring by Light increases the value of the account since officials do not come to measure;

• No idea what is the reason for the increase.

The above listing reflects not only the consumer's negative image of the utility, but also about the way in which the use of electric energy was being repressed by common sense. Many believed that electric power was a natural resource, something inexhaustible, abundant, a gift of nature. In this sense, they were not seen as consumers of energy but as users. That is, electric power was seen as a non-product, not a commodity. On the other hand, what was clearly understood as a commodity for them were the appliances obtained through credit, which is a system undoubtedly perceived by them as the result of a commercial relationship.

In 2009, with the arrival of the State presence via UPP and the reinforcement of supervision under the popular practices which is illegal electricity use, the notion of "energy consumption" is installed in the favela and is sometimes read from the perspective of "punishment". Even now that electricity is understood not as a gift of nature but as a productive process - as a consequence of a scientific advent - consumers demonstrate ignorance about the tariff details of the product. Therefore, the electric power company is perceived as invisible to the consumer.

The survey was conducted by Revolusolar from April to September in 2017 targeting approximately 120 residents in Babilônia. The purpose of this survey is to understand how much costs are consumed in Kwh/month per household in Babilônia. Due to the facts mentioned in previous chapters, it is important to calculate a fair price of electricity and the demand of electricity considering the social/economic conditions of residents in Babilônia. The survey tries to understand the payment possibilities of the residents as well which is necessary to analyze the feasibility of solar PV project.

The questionnaire comprises four main categories: 1) Electricity consumption by each electrical appliance, 2) Expenses of electricity bill by Light, 3) Social dimension on households, 4) Social dimension on solar energy and interests in cooperative.

In the first category, we can check the quantity, power (W), minimum daily use time, consumption (kWh), frequency of use of various electrical appliances such as TV, washing machine, electric fan, incandescent lamp, florescent lamp, LED lamp, electric shower, refrigerator, air conditioner, computer.

In the second category, general information regarding the electricity bill by Light is covered. After the new digital consumption meter for each house was installed, this bill has been an extremely controversial issue. Therefore, the amount of consumption and the cost of electricity on the bill is a key number to comprehend the 'official' figures of electricity in Babilônia. Indeed, the questionnaire includes whether the residents think that the electricity cost has increased in recent years after the regularization of the service by Light in 2010 and whether they could not pay the bill in time. It also covers the questions about credibility of the new digital meter and social tariff for electricity.

In the third category, the social factors such as the length of residence, the number of household family, monthly income, electricity usage habit are examined.

In the last category, we can confirm interest of residents regarding solar energy and cooperative participation. Solar energy and cooperative are still very new concept for inhabitants in a favela so it is a good chance to examine if they are willing to participate in the solar PV project.

Therefore, this research intends to evaluate the current state of residents in related to electricity issue in Babilônia and the feasibility of solar PV implementation in the long term.

There are a few things to keep in mind regarding the revision of the survey's result for this study. Firstly, the number of interviewees which is used to analyze each aspect is not always the same and it varies depending on each question. The reason is that although the total number of interviewees are approximately 120, not every interviewee answered all the questions and some interviewees gave a vague answer to be classified for the question.

As mentioned above there is the inaccuracy of official number of population and households about Babilônia, however, I will refer the data from IBGE in 2010 to analyze this study, which are 2,451 residents and 777 households. Therefore, this survey represents about 8-15% of total number depending on the question.

5.1. Electricity consumption by each electrical appliance

In this part, the questionnaire is made for checking the consumption of ten electrical appliances at house – TV, washing machine, electric fan, incandescent lamp, fluorescent lamp, LED lamp, electric shower, refrigerator, air conditioning, and computer. The questions are composed of the quantity of each appliance, the power consumption P(W), the daily time use (min), the monthly consumption (kWh). The main objective of this part is to check the detailed consumption of each appliance which is a useful data to analyze the consumption behavior of consumers and with this information we can estimate the approximate electricity demand of a favela before developing a solar PV project. Additionally, calculating the actual monthly consumption of each household can be used to verify whether the electricity bill of Light is correct since there is a strong distrust between residents and Light about the electricity bill after changing to the digital clock. Total 99 households answered to the questionnaire (about 13% of total households).

Type of electrical appliances	**Average quantity**
TV	1.51
Washing machine	0.9
Electric fan	1.64
Incandescent lamp	2.42
Fluorescent lamp	5.17
LED lamp	0.87
Electric shower	0.89
Refrigerator	1.17
Air conditioning	0.16
Computer	0.09

Table 7 Average quantity of electrical appliances of each interviewee

Most of interviewees (99) are households and only 4 of them are commercials. Therefore, the result of average quantity of electrical appliances represents more as an example of a household. According to Table 8, one of the remarkable things is that averagely each household has more than one TV (1.51). This could be resulted by the fact mentioned above – stimulating to increase of credit which enabled the purchase of appliances. This could be related to the desire of inhabits in favelas expressing that they also could have TV, especially a big screen one, like the others of the society. It is common to see people turning on TV for all day but very sometimes there is no watcher.

Another point is that the average quantity of fluorescent lamp (5.17) is double than the incandescent lamp (2.42). The reason could be the energy efficiency campaign of Light and the government. However, the use of LED lamp (0.87) is much lower than the others considering the higher price of LED lamps.

Indeed, the average quantity of electric shower (0.89) is lower than 1. It is possible to assume the reason due to its extremely high power consumption. Comparing the other appliances such as TV, averagely 60 P(W), and refrigerator, averagely 104 P(W), the power consumption of electric shower was 2375 P(W), minimum 1500 – maximum 5000 P(W). This incomparably high power consumption makes the electricity bill soar. Therefore, residents endeavour to reduce the use of electric shower, which is very hard considering the high temperature of the city, especially in summer. Related to the electric shower, the average quantity of air conditioning is extremely low (0.16) and residents depends on mainly electric fans (1.64).

In conclusion, asking the average time of consumption of each appliance with 99 interviewees, the average electricity consumption 134.38 kWh monthly per each household was calculated.

5.2. Expenses of electricity bill by Light

The payment of the bill does not always represent that its consumers approve the values attributed to its consumption. Consumers have a strong distrust of Light and one of the reasons results from the fact that the electricity distribution is practically a "natural monopoly".

For the Brazilian, the electricity bill is not only a reflection of its energy consumption, but is understood by much of the common sense as revealing a citizenship status, especially if we take into account that the account is equivalent to proof of fixed housing, something required as an important document in the acquisition of credit in stores, enrollment in educational courses, entry as a worker in the labor market and so on.

To gain understanding how much the residents in Babilônia pay the electricity bill to Light in average, Revolusolar asked residents the client code of their bill. With this code, it is possible to access to all the information of each bill on the website of Light (https://agenciavirtual.light.com.br/agv). This bill contains the monthly consumption of electricity, the price per unit, the total cost, and the tariff flag of the month. Therefore, after checking the bills of all the interviewees, I only chose to refer 58-60 cases out of 120 (total interviewees), which is possible to be applied for a study to show the consistency of data. This table as below presents the total yearly consumption kWh of 58-60 households from January to December of 2017. 13 households are low income residents.

Period	**Jan 17**	**Feb 17**	**Mar 17**	**Apr 17**	**May 17**	**Jun 17**	**Jul 17**	**Aug 17**	**Sep 17**	**Oct 17**	**Nov 17**	**Dev 17**	**Average**
Total	**13,113**	**15,680**	**15,481**	**11,280**	**10,392**	**9,795**	**9,505**	**9,797**	**9,319**	**10,758**	**10,939**	**12,320**	**11,532**
Quantity	59	60	60	60	58	58	59	59	58	60	59	60	-
Median	222	261	258	188	179	169	161	166	161	179	185	205	-

Table 8 Total yearly consumption kWh, per month, of one household

The result (Table 9) shows that the electricity consumption is closely related with the temperature condition of each season. During the summer months of December, January, February, and March, the total consumption is much higher than the winter months of July, August, September (Figure 24, 25).

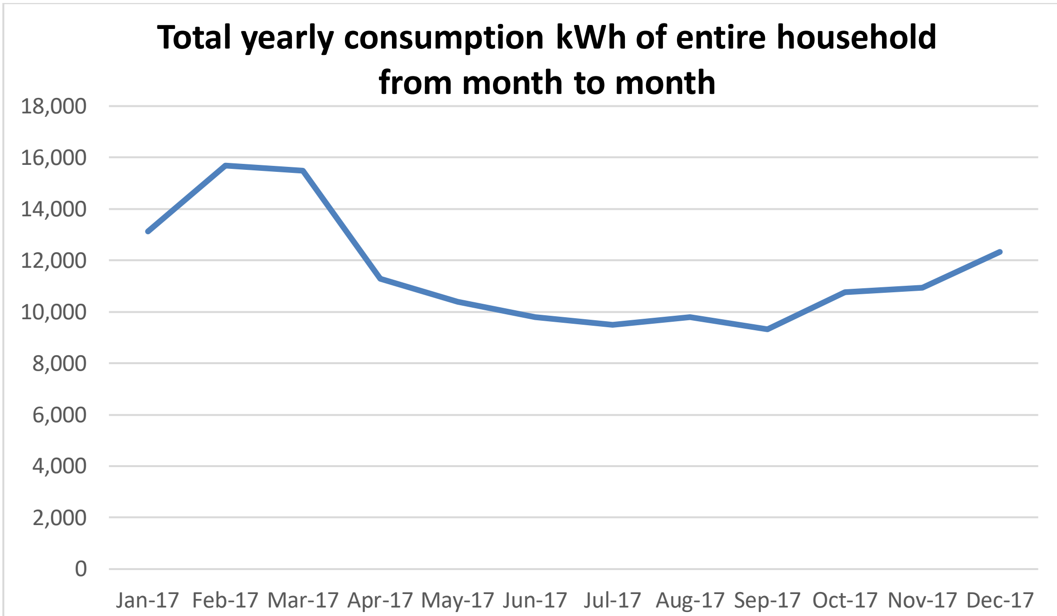


Figure 24 Total yearly consumption kWh, per month, of one household

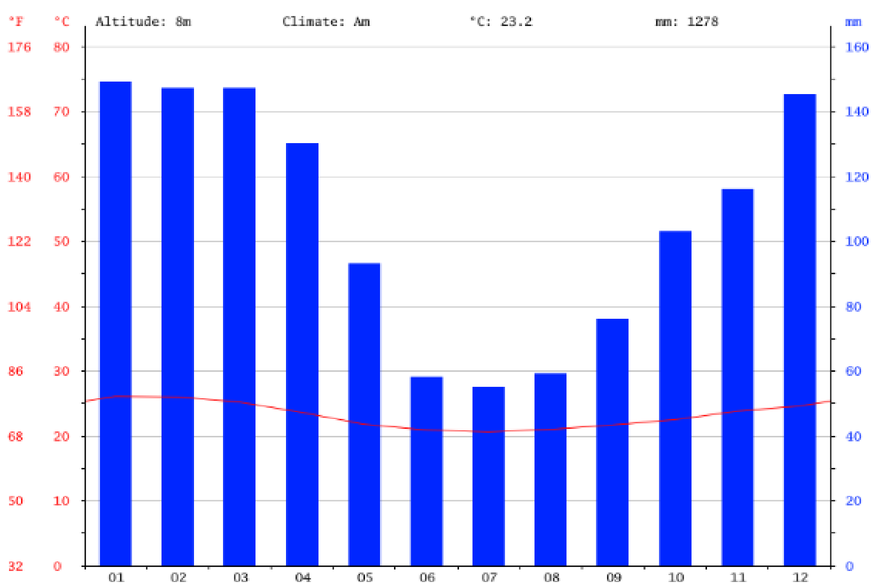


Figure 25 Climograph of Rio de Janeiro

(Source: (CLIMATE-DATA.ORG)

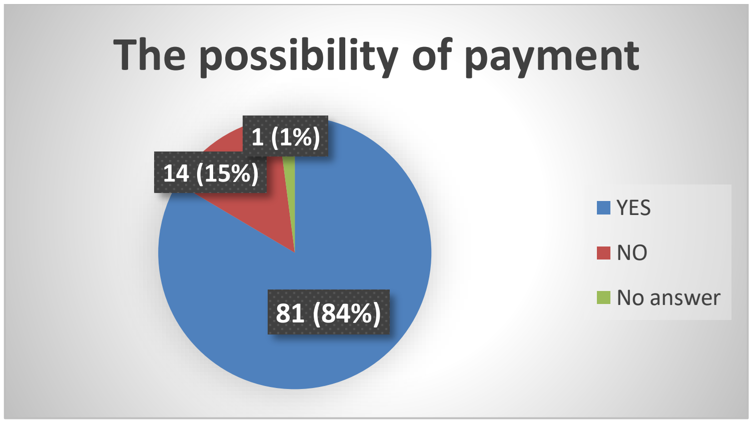


Figure 26 The possibility of payment

Regarding the financial impacts on the slum dwellers' domestic budget, the survey revealed that 84% of respondents to the questionnaires pointed out that they are able to pay the electricity bill, against 15% who claim impossibility of paying the bill and 1% who chose not to respond (Figure 26). A curiosity this data reveals is that although the great majority claim to be able to afford the payment, they say that the payment is made with a lot of "difficulty". Thus, the payment of the bill is not always carried out. Additionally, only 17% of interviewees were household with social tariff which receives discounted cost for the electricity bill.

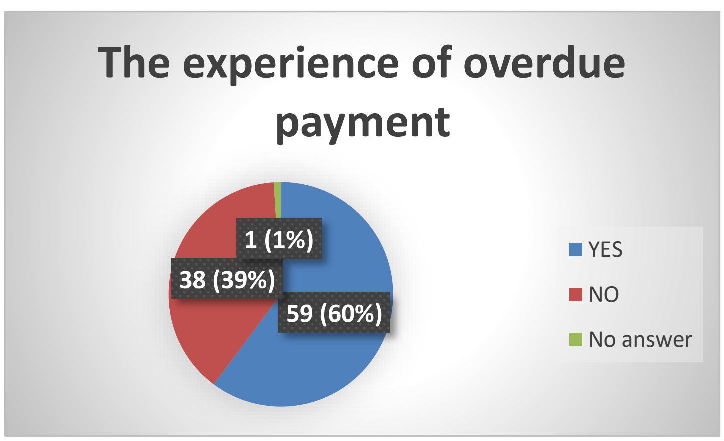


Figure 27 The experience of overdue payment

For the difficulty of the payment the bill, 60% stated that they had already delayed the bill, while 39% stated that they had not delayed (Figure 27). It is notorious that the value to be paid for electricity represents an impact on the family budget of residents of Babilônia. Interviews affirmed that the delay has already become a frequent operation among the neighborhood and may occur several times in the year.

The complaint about the difficulty of paying the bill can present even more sharply in drought times, since in these periods the level of water storage in the hydroelectric dams is below so that the Federal Government usually opts for a readjustment of the tariff of Light with the tariff flags system.

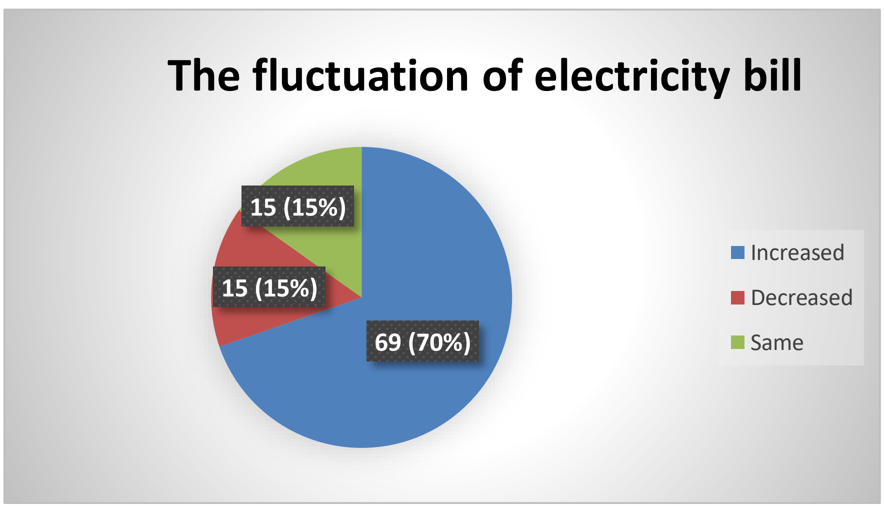


Figure 28 The fluctuation of electricity bill

Although most residents (70%) believe that the electricity bill has increased in recent years, the opinions on the period that detected the increase are not unanimous among them (Figure 28). Some believe that the rise of the account happened with the change of the analog clock to the digital one; others bet that the period is related to the installation of new poles in the community; there are still those who claim that the arrival of winter or the beginning of summer drive the rise in prices and others say they have perceived the increase but are unaware of the existence of a specific period for it to happen.

According to the record of interviewer, one of the interviewees pointed out that the price increased from R$ 40 to R$ 800. Another resident also said that It was R$ 60 now is R$ 320. This fact forced the residents to seek alternatives to reduce electricity consumption to maintain a balance in their family budget.

Residents answered about the reasons of the fluctuation in the price. From the answers believing the price increased, the interviewees assumed as follows: constant increases in the electricity rate, illegal electricity use by someone, inflation for all utilities, introduction of the differential tariff rates with flag tariff system, error of the digital clock, problem of electricity grid, abuse of electricity, regularization of Light, introduction of social tariff and some irregularities in the building. On the other hand, from the answers believing the price decreased, a few people answer that they disconnected the appliances and tried not to stay at home much time. Above all, many people said they don't know the reason or don't understand the situation.

Interviewees also answered how they tried to reduce the cost if it had increased. The most common answer was trying to disconnect the appliances as mentioned above. Also, many of them changed the appliances to more efficient ones, especially lamp and tried not to use electricity as much as they can. Even few people threw away their appliances not to consume electricity anymore. But many people answered that they didn't see the difference even after those efforts. Some people don't do anything because there are not many appliances at home in any case. A small number of people responded they tried the Light recycling system, went to the office of Light to make complaints directly and tried to do the illegal electricity use.

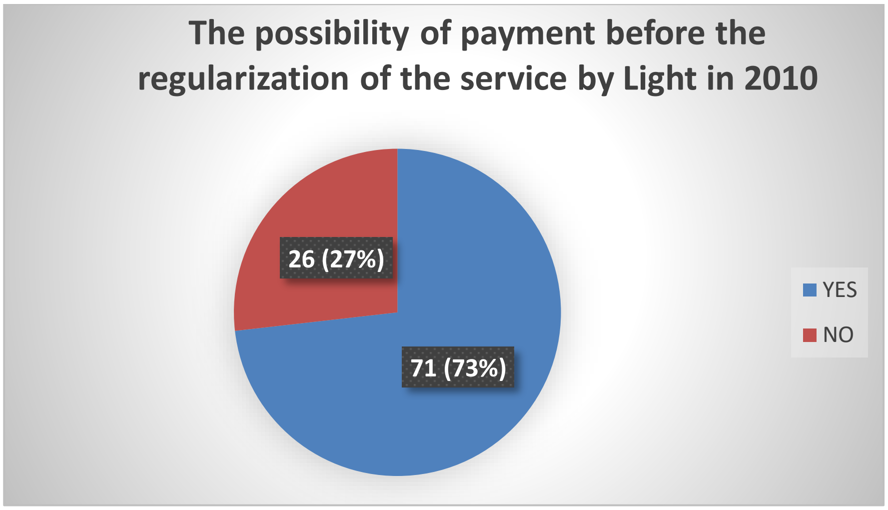


Figure 29 The possibility of payment before the regularization of the service by Light in 2010

Among the respondents, 73% said they paid the electricity bill before the regularization process, compared with 27% claim the opposite (Figure 29). It is known that addressing issues such as the regularization of electricity in Babilônia still seems like a taboo among residents. Some factors add up to this point of view, one of them is that there is a moral constraint in using the illegal electricity use to obtain electricity under socially and / or judicially penalized. Thus, it is possible to assume that the data in the chart above are also implicated under this moral fear on the part of the interviewees and they might not answer the truth. Most of residents answered that they had paid under R$ 100 before the regularization.

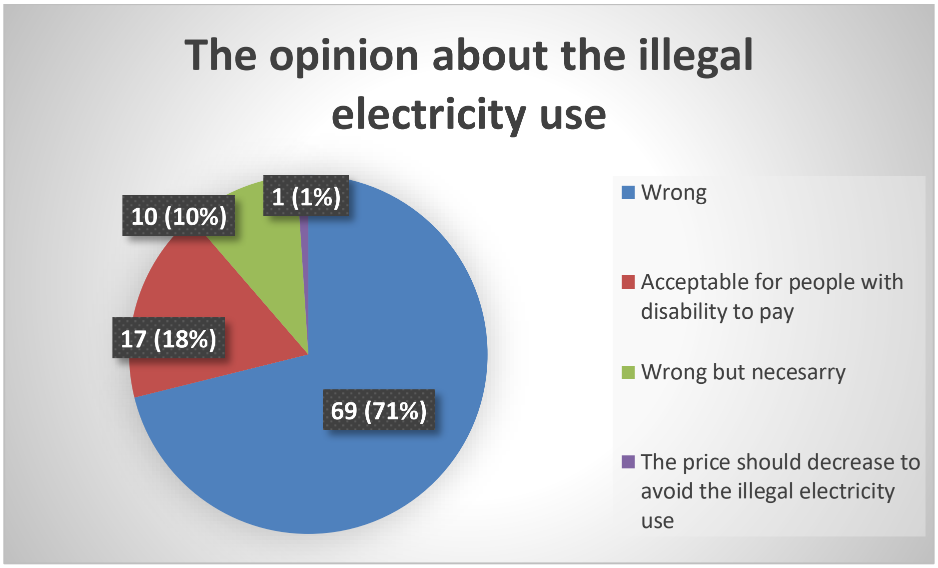


Figure 30 The opinion about the illegal electricity use

According to figure 30, most of residents (71%) didn't agree with the illegal electricity use and said it is an absolutely wrong action. They complained that the honest clients have to pay more due to the illegal electricity use of the others. 18% of people responded they can accept this considering that there are clients that cannot pay the bill due to the economic difficulties. In a similar but different vein, 10% of interviewees answered it is a wrong attitude but at the same time it is necessary for some people. 1 person was litmusless mentioning that the electricity price should decrease in order to avoid this illegal situation. This result shows a tendency against the prejudice that residents in favelas will be favorable for the illegal electricity use. Additionally, some interviewees even know that who were committing it.

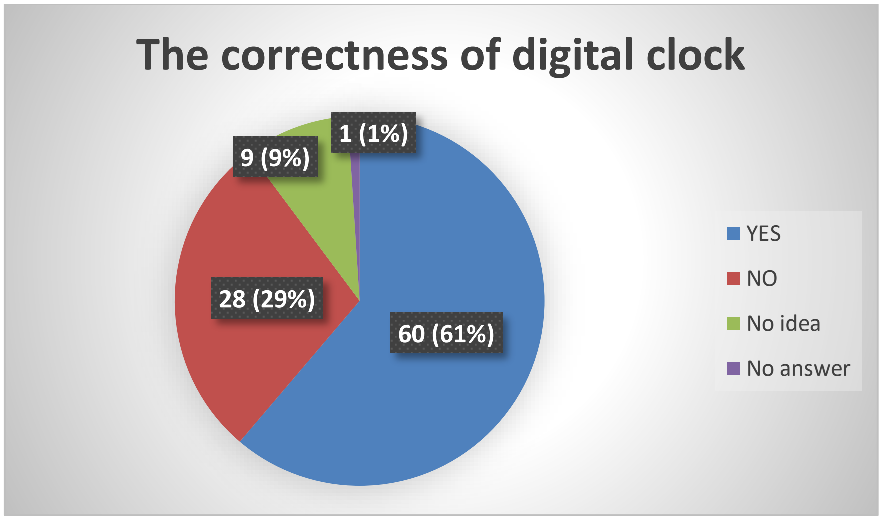


Figure 31 The correctness of digital clock

61% of residents think that the digital clock which was installed after regularization works correctly, however, 29% were doubtful (Figure 31). Most of interviewees responded they can get access to the digital clock but some people complained that they do not know how to read the digital clock and it makes them difficult have reliability with it. Since managing and controlling this digital clock are out of their hands, building trust between residents and Light has become a controversial issue.

Maybe the fundamental issue is not if the digital clock itself corrects or not. It could work correctly or the residents feel that the price on the bill is higher than what they expected because their equipment is so old so that consumes more electricity, which is hard to feel as a consumer. However, if the relationship between Light and residents were good, they just could call Light to come to check what is the main problem what they face and to fix and solve. But, if it were not, the problems could not be solved and kept going on and on. Light has a huge problem related this with not only people from favelas but also low salary class. This situation causes that the residents try to fix it by themselves which is absolutely dangerous because they don't want until Light comes to fix it.

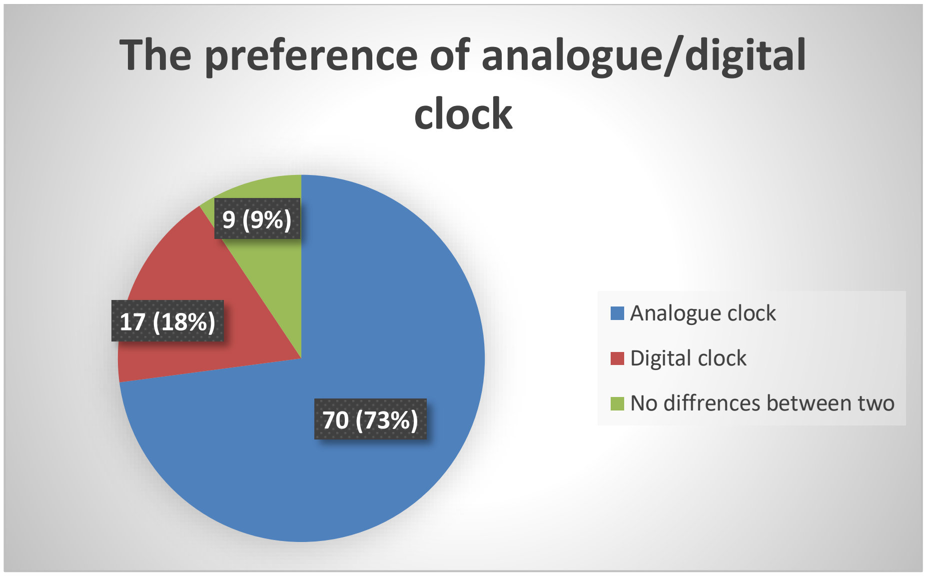


Figure 32 The preference of analogue/digital clock

73% of residents said they prefer the old version of analogue clock than the digital clock (Figure 32). The reasons are related with the ones mentioned in the previous question.

Since the residents can get discount for their electricity bill by using the Light recycle program, there was a question asking if the residents have the Light recycle card. The result shows that not many residents are aware of the program or are not interested in using it (64%). The reasons could vary but one of the possible reason is that the discount is not significant even though they bring the recyclable materials. Most of interviewees who has participated in the program answered that the discount is very little money. Residents considered that the aim of the project is great but it should be improved to attract more participation.

5.3. Social dimension on households

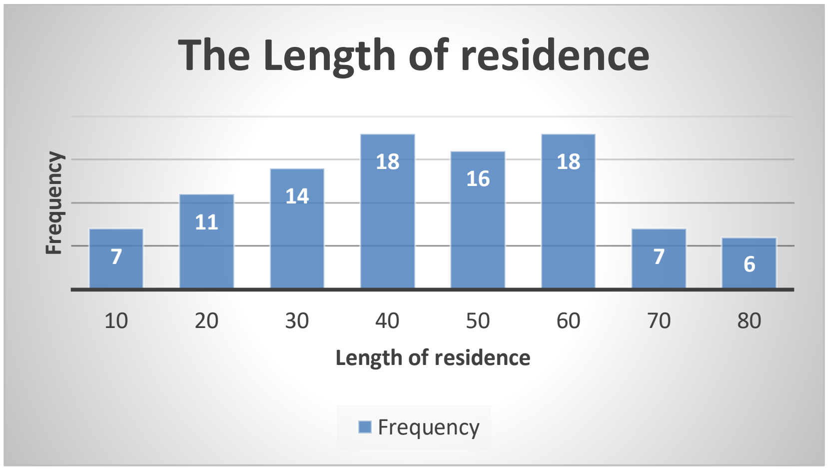


Figure 33 The Length of residence

All of interviewees has been living in Babilônia for more than 10 years and more than half of them has been living more than 40 years (Figure 33). The average length is 44.11 years. There was no question about their age on the questionnaire.

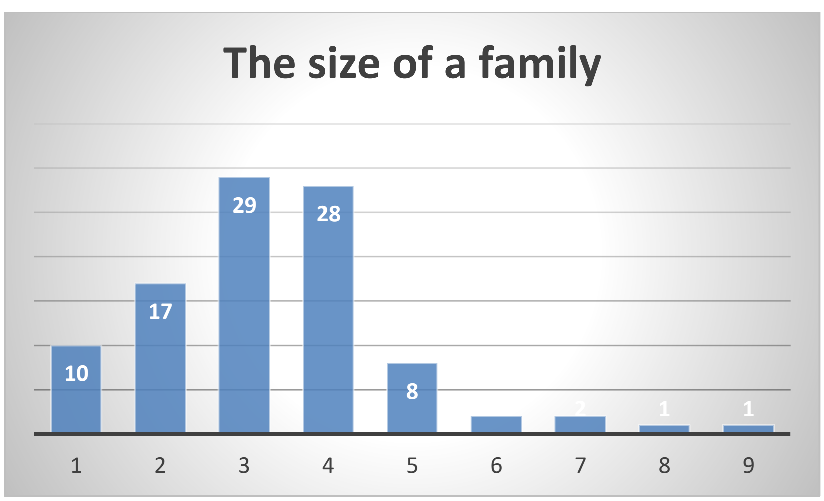


Figure 34 The size of a family

The most frequent number of family size are 3 and 4 members and there are higher number members such as 8 and 9 persons (Figure 34). It is important to check the size of a family because the electricity consumption has a very close relation with the number of family. Most of family has at least one person who works and has salary to support the rest of members. The majority of household live in their own house with ownership but 3 household lease the house.

To comprehend more comprehensive social context, their working and salary situation were also checked. Residents in Babilônia work in various sectors such as clinic, shop, cleaning, concierge, day laborer, school coordinator, service assistant, craftsman, housekeeper, salesman, bricklayer, fireman, driver, laundry, night watch, hairdresser, secretary, teaching, graphic designer, trade, chef, moto taxi driver, artist, mechanic, electrician, newspaper delivery, merchant, deliveryman, environmental agency, project coordinator. Also, many of residents are retired and do domestic works.

The average monthly income of interviewees was R$ 1,400 (USD 370). The least amount of salary was R$ 300 and the highest one was R$ 3,800. In fact, not all of them answered their exact salary since it is their privacy and delicate part. Roughly half of them gave the exact number but the others only answered '1 or 2 salaries'. In this case, I applied R$ 1,000 for 1 salary by considering the average monthly income R$ 965 mentioned in the book "Um País Chamado Favela" in 2014.

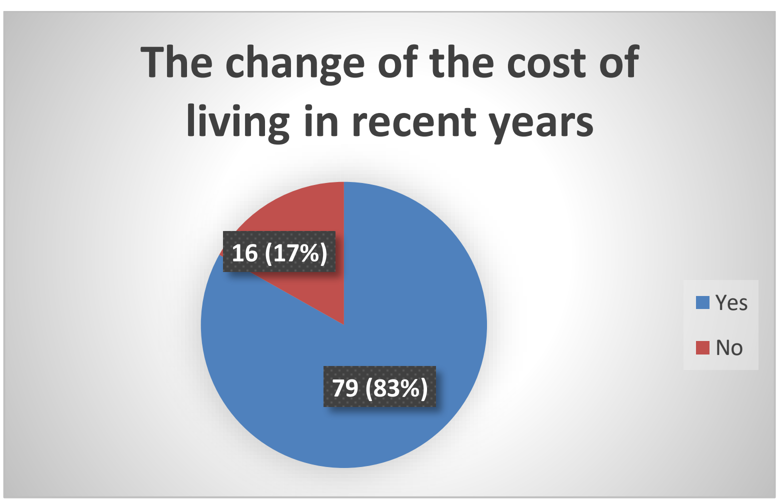


Figure 35 The change of the cost of living in recent years

83% of residents answered that the cost of living has increased in recent years and 17% of them responded it is almost the same (Figure 35). The amount of increase that they assume and the period were different, however, they showed the same opinion about what was the main cause of the increase – political crisis in Brazil and the consequential lack of control about inflation. The majority of people said "everything" has become much more expensive than before.

5.4. Social dimension of solar energy and interests in cooperative

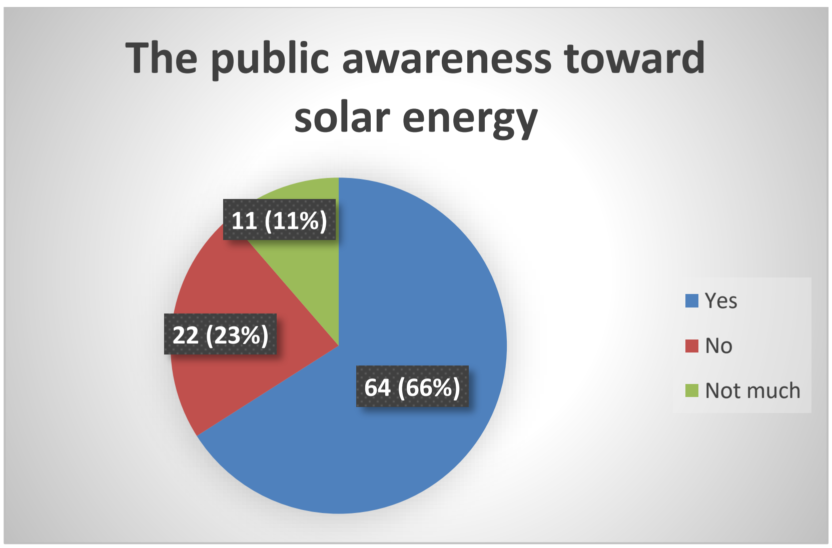


Figure 36 The public awareness toward solar energy

Before developing a solar PV project, it is fundamental to check whether the residents know about solar energy and are interested in participating in the project since it is a relatively new concept and not very affordable cost to implement in the beginning. 66% of interviewees answered that they have heard about the solar energy and 23% said they have not heard about it. The rest of 11% said maybe they have heard about the technology (Figure 36).

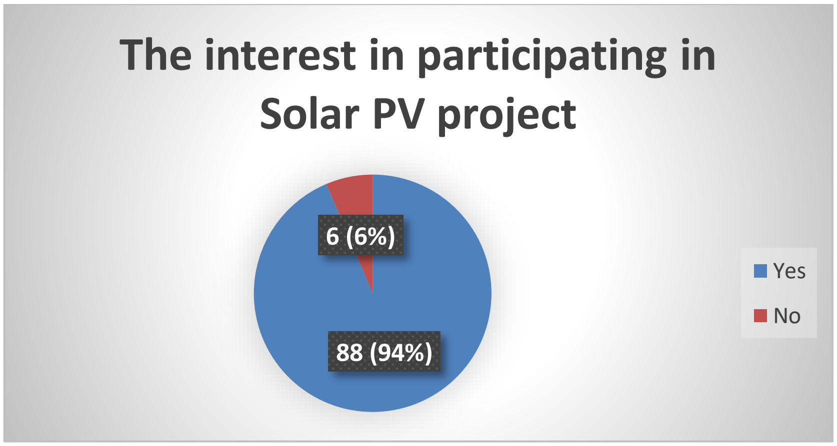


Figure 37 The interest in participating in Solar PV project

Additionally, 94% of residents said they have interests in participating for solar PV project in the way of buying electricity with Revolusolar if there was a guarantee that the credits would be distributed to members living in Babilônia (Figure 37). They mentioned the possible amount of payment to participate to the project in the beginning. The average amount was R$ 72 per household and minimum R$ 10, maximum R$ 200. The amount they suggested were lower than the current cost to Light in principle.

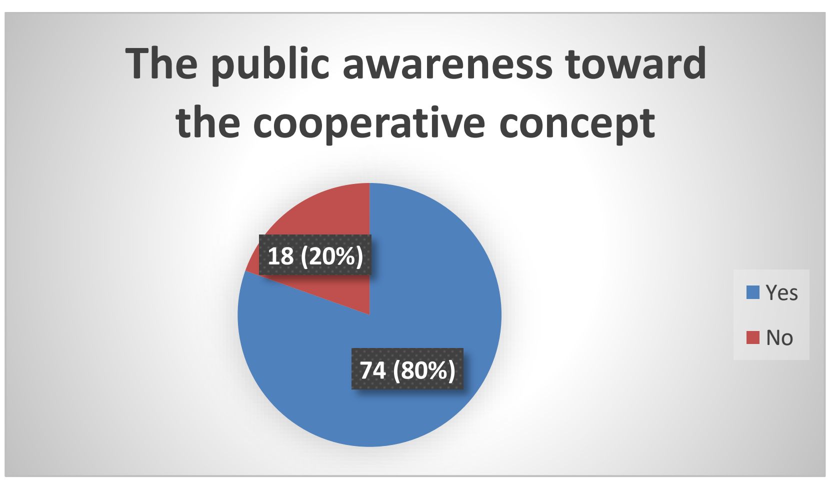


Figure 38 The public awareness toward the cooperative concept

Cooperative could be an attractive concept to achieve the project with the participation of residents in Babilônia (Figure 38). Therefore, the more there are interests of inhabits about the concept, the more there are high possibilities to implement the project. Residents being aware of cooperative have an image about this concept – Group of people working for the same purpose and working voluntarily.

5.5. Comparison of electricity consumption between the bill and self-calculation

December/2017	Cost of bill	Consumed kWh on the bill	Estimated kWh by Revolusolar	Consumed vs Estimated (%)
Total	R$ 10,204	12,163 kWh	7,699 kWh	
Quantity	59	59	59	
Average	R$173	206 kWh	130 kWh	58%

Table 9 Comparison of electricity consumption between the bill and self-calculation

On the basis of data from the survey, we can draw a comparison between the actual electricity consumption (by the price and kWh) from the Light bill and the self-calculation based on the individual questions about daily electricity consumption of residents (the first part of the questionnaire). To have the latest data, I used the bill from December 2017 and chose only 59 cases that have almost complete answers about their daily consumption for each appliance.

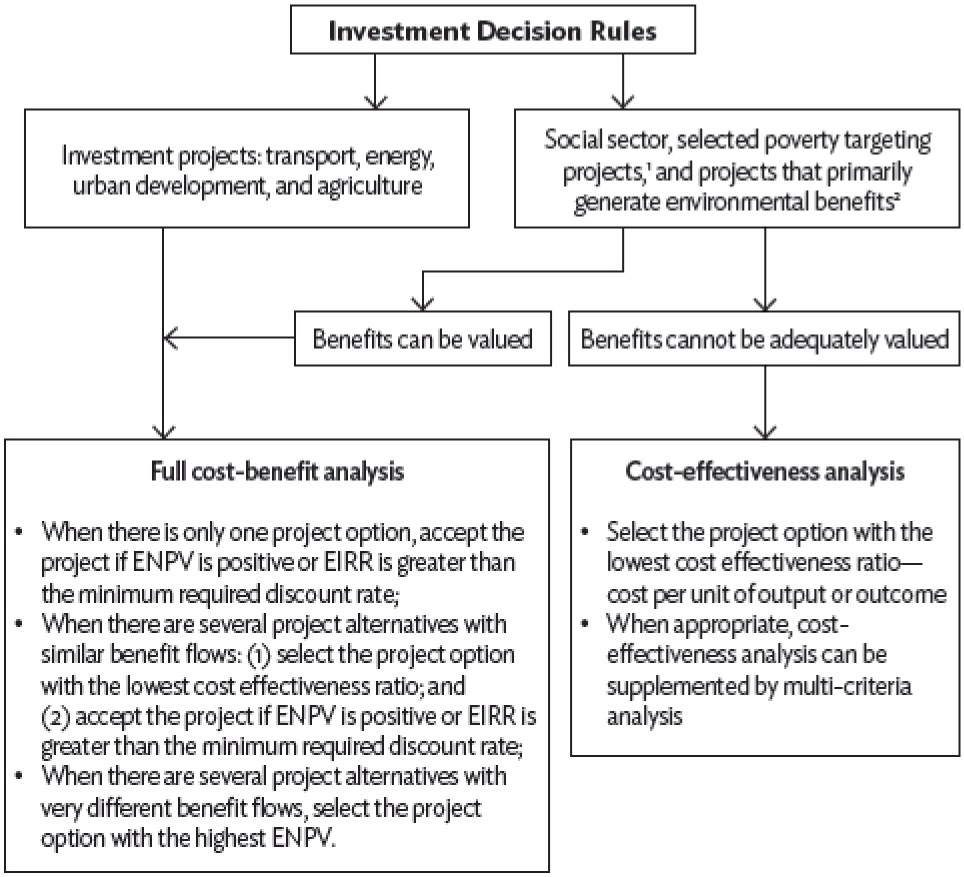
The total electricity cost and consumption of 59 households were R$ 10,204 and 12,163 kWh. The average electricity cost and consumption of each household was R$ 173 and 206 kWh. However, the total estimated consumption of electricity for 59 households were 7,699 kWh and the average was 130 kWh (Table 10). Therefore, the average electricity consumption of the bill was 58% more expensive than the assumption. Since the answers of interviewees are basically based on ‘assumption’, it cannot be 100% correct. However, we still draw a conclusion that there are some numerical gaps between the Light bill and the actual consumption. This number of 59 households represents 7.6% of all the households (777) in Babilônia.

6. ECONOMIC ANALYSIS IN BABILÔNIA

6.1. Risks for financing and investment decision rules

U.S. Agency for International Development presented barriers to commercializing renewable energy technologies. There are crucial points which can be applied to this solar PV project as well and it is important to develop a financing model considering possible risks.

- Renewable energy systems tend to have little or no fuel, operation and maintenance (O&M) costs but their initial unit capital costs tend to be much higher than fossil generation systems.
- Renewable energy projects are generally smaller in scale and therefore require smaller total investments. As a consequence, many commercial banks, utilities and established independent power producers (IPPs) are not interested in pursuing these smaller investments.
- Renewable energy projects are not able to guarantee that the fuel will be available when needed since it may depend upon environmental conditions.
- Small, independent and newly established renewable energy project developers often lack the institutional track record and financial inputs necessary to secure non-recourse project financing.
- On a global scale, renewable energy projects tend to be developed by smaller entities with weak financial positions. They are frequently unable to leverage the financial resources needed and as a result are unable to attract equity investors or secure debt financing (U.S. Agency for International Development, 2002).



EIRR = economic internal rate of return, ENPV = economic net present value.

[1] Such as rural roads and rural electrification.

[2] Such as pollution control, protection of the ecosystem, flood control, control of deforestation, and disaster risk management.

Figure 39 Investment Decision Rules

(Source: ADB Economic Research and Regional Cooperation Department)

There are three main ways to evaluate investment opportunities, namely capital budgeting. Assessment criteria are needed to assess the priority of investment opportunities. There are three main concepts of this evaluation criteria: Net Present Value (NPV), Internal Rate of Return (IRR), and payback period. To invest a project, it is essential to check its cost and benefit before implementing. Figure 39 suggests how to decide an investment depending on the condition whether benefits can be valued or not. Implementing a solar PV project is categorized as an energy sector and the cost and benefit can be valued. Since there is only one project option, the key point is that if NPV is positive or if IRR is greater than the minimum required discount rate.

The NPV is the sum of the differences between the discounted benefit and cost flows, and can be estimated as

$$\text{ENPV} = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Where *Bt* is the gross economic benefit in year *t, Ct* is the sum of economic costs (including capital costs, operating maintenance costs, and negative terminal values) in year *t, r* is the required economic discount rate, and *n* is the project life. The IRR is the discount rate at which the NPV becomes zero, and it can be estimated from the following:

$$\sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} = 0$$

Where *r* is the IRR, at which, the sum of the discounted stream of economic benefits equals that of the economic costs of a project (Asian Development Bank, 2017).

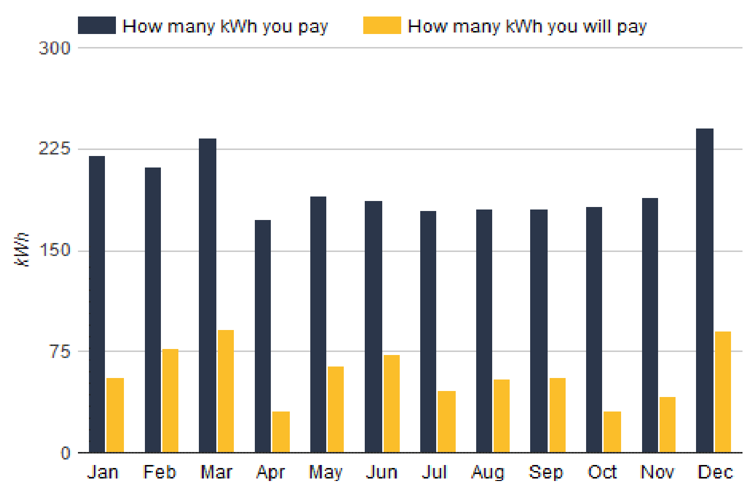
6.2. Estimated production and consumption of electrical energy

The total electricity consumption of 58-60 households were 138,379kWh in 2017. The average per month were 11,532kWh in total and 195kWh per household. Therefore, to calculate a NPV of a single household, I choose a household from the survey which has 198kWh of average monthly consumption, located in Rua Vila do Sossego in Babilônia.

CÓDIGO	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Sum	Average
D 0309-2	220	212	233	173	190	187	180	181	181	183	189	241	**2370**	**198**

With this data, the following information is calculated by using the website 'America do Sol' [1]. Based on the given address, the possible capacity of PV (power) is 1.2 kWp and the occupied area by system is from 8 to 11m^2. The approximate inclination of modules is 23 ° and annual yield would be 1,378 kWh/kWp. Currently, the total electricity consumption of this household per year is 2,370 kWh from the Light bill in 2017. After installing solar PV, 1,654 kWh would be generated by PV and the consumption from Light would decrease up to 716 kWh (figure 40).

On this study, I set the period of this project maximum 10 years. The principal reasons are because of lack of savings by residences and the unstable living environment of favelas. For the residences in favelas, it is hard to invest for such a long term project. The reason is if the money which they invest is something they cannot use in the near future, they would be reluctant to invest the money. This is a critical point since they do not have sufficient savings in general. Indeed, since the tension in favelas related to the security has been always changing, it makes difficult to decide such a project for a long period. However, the length of residence in Babilônia is 44.11 years shown on figure 38, which is significantly stable and better conditions compared to other favelas and this is a positive factor for this study.



[1] America do Sol was made by IDEAL, GIZ, BID, OLADE, etc. The result of the sample calculated on America do Sol can be found on the next link: http://www.americadosol.org/simulador/simulation.php?id=318204&session=62e70a75978f5c694fcc4c63c4892565&id_s=1

Mês	Eletricidade total consumida	Eletricidade gerada pelo sistema FV	Eletricidade fornecida pela rede
Janeiro	220,00 kWh	164,44 kWh	55,56 kWh
Fevereiro	212,00 kWh	134,79 kWh	77,21 kWh
Março	233,00 kWh	141,39 kWh	91,61 kWh
Abril	173,00 kWh	141,49 kWh	31,51 kWh
Maio	190,00 kWh	125,28 kWh	64,72 kWh
Junho	187,00 kWh	113,58 kWh	73,42 kWh
Julho	180,00 kWh	133,84 kWh	46,16 kWh
Agosto	181,00 kWh	125,78 kWh	55,22 kWh
Setembro	181,00 kWh	125,06 kWh	55,94 kWh
Outubro	183,00 kWh	151,44 kWh	31,56 kWh
Novembro	189,00 kWh	146,56 kWh	42,44 kWh
Dezembro	241,00 kWh	150,36 kWh	90,64 kWh
Total Anual	**2.370,00 kWh**	**1.654,01 kWh**	**715,99 kWh**

Figure 40 Expected future bill (kWh) after installing solar PV

6.3. Cost calculation

6.3.1. Equipment

- Initial capital cost and contingencies

Considering the possible capacity of PV (power) is 1.2 kWp on the site, a micro solar generator packages with 1.28 kWp was applied to the calculation. According to 'Portal Solar', this package includes a micro-inverter, 4 panels, cables and etc. The micro-inverter has 10 years of guarantee and maximum 25 years with extension. The efficiency of panels is 16.5% with 3% positive tolerance. It has 72 solar cells and the warranty is 25 years. The total price of this solar generator package is R$ 7,352.74[2] (Table 11). The delivery cost of the equipment to the place where they will be installed is assumed R$300. We set R$1,000 for the monthly minimum wage on this study. Thus, the daily minimum wage is about R$40-45 considering 23 working days/month. Since this labour work needs some technical knowledge, I set R$60/person for labour cost. Lastly, as contingencies, 10% of the equipment, delivery and labour cost is added.

[2] Product information on Portal solar - https://www.portalsolar.com.br/loja/gerador-solar-fotovoltaico-de-1-28-kwp-microinversor-telha-ondulada

	Unit cost	Quantity	Total cost
Solar generator 1.28 kWp	7,352.74	1	7,352.74
Delivery cost	300	1	300
Labour cost	60	3	180
Contingencies (10%)			783.274
Total			**8,616.014**

Table 10 Initial capital cost and contingencies

6.3.2. Variable cost

- Operating & Maintenance cost

The annual operation and maintenance cost was considered to be equal to 1% of the cost of the installed system according to the report from (EPE, 2012). And the panels are only needed to sweep and clean which could be done voluntarily by the owner.

A photovoltaic system requires very low maintenance in the course of its useful life, apart from the periodical cleaning of the module that is necessary. Therefore, the operating cost is mainly due to the need to change the inverter, which is considered part of maintenance. Although the useful life of photovoltaic modules is 25 years or more, inverters last 10-15 years on average (Miranda, Szklo, & Schaeffer, 2015). Some of the innovative inverters (such as small micro-inverters which applied to this study) use distinct capacitors made for solar applications which lengthen the lifespan of the inverter to better set the lifespan of the modules they are connected to. Although various companies sell them with warranties of up to 25 years like the chosen model on this study, the exact number of extended years are not precisely verified. However, since the maximum project period is set 10 years on this study, buying an extra inverter is not considered.

- Insurance

As a precaution of panels which possibly could be broken by the existent violence of the site, 0.3% of equipment cost per year is added according to the report from (EPE, 2012).

6.4. Power generation

For this study, a price of R$6.73/Wp for the complete installed system was taken into account for the base year 2018. The estimated annual production is following with an annual loss of 0.1%[3] (Table 12). Based on the projections presented, this household produces 138kWh/month on average for the first year.

Year	1	2	3	4	5	6	7	8	9	10
Generation (kWh)	1,654	1,637	1,621	1,604	1,588	1,571	1,555	1,538	1,522	1,505

Table 11 Estimated annual power generation

6.5. Income calculation

- Total generated electricity price by solar PV (saving)

The electricity social tariff for residence is R$0.62507/kWh in August 2018 (for consumption between 101 and 220 kWh). I assume that the tariff will adjust at the same rate as the average inflation of the Brazilian economy from 2010 to 2017, which is 6.31%.

- Tax effects

On the chapter about policy analysis, I mentioned that the exemption of ICMS for solar PV generation. However, in Rio de Janeiro, Light is not yet exempting ICMS for distributed energy producers. Despite of the current situation, I am confident that in the short term this exemption will be achieved and I will calculate this study based on this assumption. As for PIS and COFINS, they are exempted by a federal law, and this exemption is actually happening in Rio de Janeiro.

[3] According to the National Renewable Energy Laboratory (NREL), the general rule of thumb is that panels will degrade by about 1% each year with the current technology.

6.6. Interest rate for financing

Possible financing options with national banks are presented in this part but the definitive conditions of a financing (interest rate, terms, etc.) will be the result of a negotiation with the banks. Therefore, I check the options to show the available view in the market today by assuming the rate in the presented level. The key point is that the conventional interest rate for the residence in favelas should be calculated over 15% per year considering their unstable economic situation.

- Caixa - Construcard

Caixa is a Brazilian public bank linked to the Ministry of Finance. It is operated as a strategic partner with the Federal Government in the infrastructure, housing, and sanitation sectors, contributing to the social and economic development of the country. It operates Social Housing Guarantee fund and the Social Development fund.

'Construcard' is a credit card from Caixa for the purchase of construction material in Caixa-accredited stores. Since 2017, a new version of Construcard offers to the individual users to finance photovoltaic systems such as power generation and panels as well up to 240 months with certain interest rates. This interest rate is given by the transaction condition of each card holder and 1.45% per month (18.86% per year) is used for this study.

The financing has two phases: Use and Amortization. The first phase is intended for the purchase of its construction material, which can be between two and six months. During this time, users only pay interest on the amounts used. The second stage, which can vary between one and 240 months, is the amortization of the balance due, that is the monthly payment of the installments until the discharge of the financing. This step only begins after the deadline set for purchases. The requirements are: to be a natural person and have a checking account in the Caixa, over 18 years old and approved in the bank's credit and registration evaluations (CAIXA, 2018).

- BNDES – Fundo Clima

BNDES is a Federal Government's main instrument for long-term financing and investment in all segments of the Brazilian economy. As a public company and not a commercial bank, BNDES evaluates the granting of support focused on socio-environmental and economic impact in Brazil. Encouraging innovation, regional development and socio-environmental development are priorities for the institution.

Fundo Clima (Climate Fund) is a program part of BNDES to support the implementation of enterprises, the acquisition of machinery and equipment and technological development related to the reduction of greenhouse gas emissions and adaptation to climate change and its effects. In the Efficient Machines and Equipment subprogram, individuals can have the support from BNDES to access to financing for the installation of solar energy systems.

The interest rate depends on the form of support, the size of the client and each item as follows. The interest rate is composed of the Financial Cost, the BNDES Fee and the Financial Agent Fee (Figure 41).

Individuals and companies		
Financial cost	BNDES rate	Financial Agent Fee
0.1% per year	0.9% or 1.4% per year *	up to 3% per year

* Beneficiaries with Gross Operating Revenues of up to R $ 90 million: 0.9% per year;
Beneficiaries with Gross Operating Revenues above R $ 90 million: 1.4% per year.

Figure 41 Interest rate of Fundo Clima

(Source: (BNDES, 2018))

Since the gross revenue of this project is less than R$ 90 million per year, I set the yearly interest rate as 4% (0.1% + 0.9% + 3%). In the case of acquisition of machines and equipment, there is no minimum value as a requirement to request this fund. The Climate Fund support up to 80% of the value of the eligible items and the maximum amount of financing per beneficiary is R$ 30 million every 12 months. The repayment condition is up to 12 years, including a grace period of at least three months and a maximum of two years.

Funding from BNDES generally focused on the mega size infrastructure projects and the requirements were not suitable for a small size project. However, since the policy of Fundo Clima changed recently, it is an opportunity to take advantage of this program.

6.7. Projected inflation and discount factors

6.7.1. Inflation tendency

The average inflation rate from 2010 to 2017 was 6.31% (Table 13). Due to the economic crisis, it increased up to 10.67% in 2015. However, it decreased again after that year and it was significantly low (2.95%) in 2017. In this study, I will use the average rate from last 8 years for the future calculation.

2010	2011	2012	2013	2014	2015	2016	2017	**Average**
5.91%	6.50%	5.84%	5.91%	6.41%	10.67%	6.29%	2.95%	**6.31%**

Table 12 Inflation rate from 2010 to 2017

(Source: Central bank of Brazil)

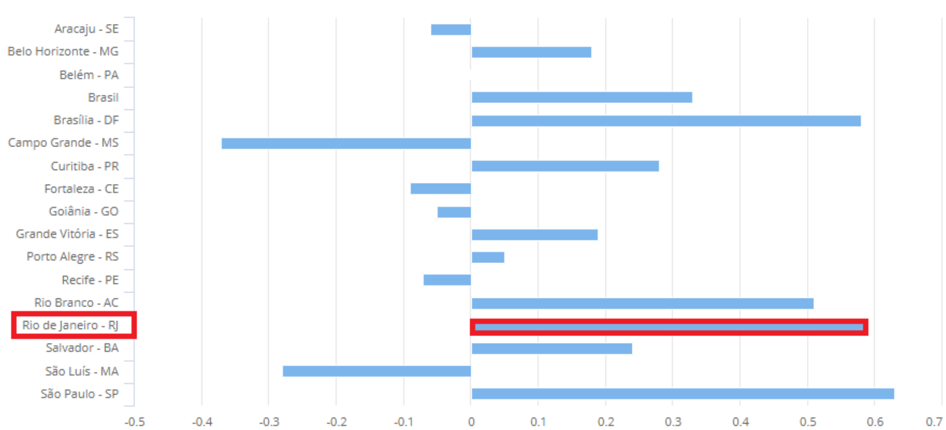


Figure 42 National Consumer Price Index - Monthly variation by city (%), July 2018

Source: (IBGE)

As shown in figure 42, Consumer price index of monthly variation in Rio de Janeiro was the second highest (0.59%) in the national level in July 2018. Moreover, the producer price index of monthly variation about manufacture of electrical machinery, apparatus and equipment was 1.7% in June 2018.

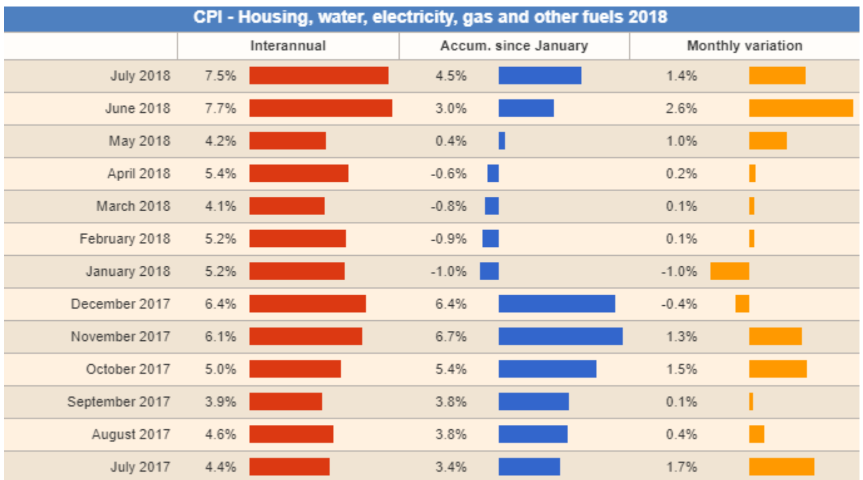


Figure 43 Brazil CPI Consumer Price Index for electricity in 2018

Source: (Countryeconomy)

Figure 43 shows that the consumer price index of housing, water, electricity, gas and other fuels from July 2017 to July 2018. Although this data includes not only electricity but also other sectors, it is possible to assume that it has similar tendency with the inflation rate. However, as considering that this is the national level data and the consumer price index in Rio de Janeiro has higher increase than the others, I will assume the electricity tariff increase in Rio de Janeiro is higher than the national inflation rate.

6.7.2. Discount rate

As mentioned above, I considered two ways of funding from Caixa and BNDS and they have different interest rates, 18.86% and 4% per year. Considering that the dwellers in Babilônia do not have enough savings to invest their own money as equity, the portion of debt is significantly high. In the case of Fundo Clima from BNDS, there is limit that this funding supports up to 80% of the value of the eligible items. It means that the rest 20% should be the equity. To calculate the discount rate of combing the equity and loan, I use capital asset pricing model (CAPM) and weighted-average cost of capital (WACC) models.

The discount rate is the opportunity cost of capital (as a percentage of the value of the capital). The opportunity cost of capital is the return on investments forgone elsewhere by committing capital to the investment under consideration. In investment decisions, the opportunity cost of capital is the cut-off rate, below which it is not worthwhile to invest.

Investors in energy projects expect a rate of return from projects to compensate them for the following: a minimum acceptable real return available in the market (risk-free rate of interest), the risk of investing in the project, taxation and also inflation. Regulated energy utilities have a risk, which is lower than the average market risk. A stock's sensitivity to change in the value of the market portfolio is known as beta. In a competitive market, the expected risk premium varies in direct proportion to beta (Hisham Khatib, 2015). This is the capital asset pricing model (CAPM), simply defined as $Kp = KRf + \beta \cdot (Km - KRf)$.

Expected Rate of Return (Equity interest rate)

= Risk-free Rate + β {Expected Market Return – Risk-free Rate}

WACC is the weighted-average cost of the firm's equity and debt. WACC is a common tool used by energy investors for discounting cash flows and assessing the viability of the investment. It, unlike the discount rate, does not directly reflect risk; but this should be embedded in the choice of the expected return and the cost of debt.

$$WACC = \frac{P}{P+D} \cdot Kp + \frac{D}{P+D} \cdot Kd \cdot (1 - T)$$

P: Share of equity in company structure

D: Share of third-party capital in the structure of the company

Kp: Cost of equity of the company

Kd: Cost of third-party capital

T: Taxation on profits

P	80.00%
D	20.00%
P/D	4.00
P+D	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

Table 13 Discount rate factors

I use the Beta for the American market, which I obtain from the site of the Aswath Damodaran (http://pages.stern.nyu.edu/~adamodar/). This is evidently a similarity approach, since there are not enough capital company opened with a significant business area in solar energy in Brazil, so I understand that this solution can be alternative.

Damodaran presents the updated value for the unleveraged beta corrected for cash as 0.47. The leveraged beta is calculated as follows:

Leveraged beta = Unleveraged beta x

(1+ P/D (1 – Tax rate))

Thus, the leveraged Beta is 1.83 = 0,47 x (1+4*(1-0,275)). The rate of SELIC[4] is used for KRf (risk free rate) and Km is given by the data of Damodaran. Thus, the equity interest rate (Kp) is 27.28% = 6.4% + 1.83 (17.79% - 6.4%).

In conclusion, the discount rate using WACC is 7.78%

= 8/10 x 27.28% + 2/10 x 4% x (1 – 27.5%)

I will explain in scenario analysis in detail the different financing models using this discount rate (Table 14).

6.8. Parameter table

This parameter table is comprised of the default value in general. To calculate various scenario analysis, different number is used depending on the scenario.

[4] The Sistema Especial de Liquidação e Custodia (SELIC) *(Special Clearance and Escrow System)* is the Brazilian Central Bank's system for performing open market operations in execution of monetary policy. The SELIC rate is the Bank's overnight rate. (Source: Wikipedia)

Item	Value	Units	Sources	Comments and shortcomings
Total electricity consumption of 58-60 households in Babilônia in 2017	138,379	kWh	Survey from Revolusolar 2017	
Average electricity consumption per month of 58-60 households	11,532	kWh		
Average electricity consumption per month per household	195	kWh		
Total electricity consumption in 2017 from a sample household (Code D0309-2)	2370	kWh		This sample was chosen due to its similar amount of the average of 58-60 households Address: R. Vila do Sossego – Leme, Rio de Janeiro, Brazil
Average electricity consumption per month from a sample household (Code D0309-2)	198	kWh		
Capacity of PV (Power)	1.2	kWp	Self-calculation on America do Sol 2018	
Occupied area by PV	from 8 to 11	m2		
Approximate inclination of modules	23	°		
Annual yield	1,378	kWh/kWp		
Expected electricity consumption from Light per year	716	kWh		
Expected photovoltaic generation per year	1,654	kWh		
Expected photovoltaic generation per month	138	kWh		
Power generator capacity	1.28	kWp	Portal solar	
Micro-inverter lifespan	10	years	Miranda, Szklo, &	Inverters last 10-15 years on average

			Schaeffer, 2015	
Micro-inverter warranty	10	years	Portal solar 2018	Maximum 25 years. The extended warranty is obtained by paying an additional 5% on the value of the kit.
Solar panels lifespan	25	years	Portal solar 2018	
Solar panels warranty	25	years	Portal solar 2018	
Annual loss of generation by panels	0.01	%	NREL 2018	
Price of power generator 1.28 kWp	7,352.74	R$	Portal solar 2018	This price includes all the equipment as a package
Labour cost	60	R$		Per person
Price of panels	949	R$	Portal solar 2018	Maximum potential power 320W
Residual value of panels	15	%		http://cdn.intechweb.org/pdfs/12517.pdf https://ases.conference-services.net/resources/252/2859/pdf/SOLAR2012_0783_full%20paper.pdf
Price per Wp for the complete installment	6.73	R$		CAPEX/Wp
Annual operation and maintenance cost	1	%	EPE 2012	It is considered to be equal to 1% of the cost of the installed system
Insurance cost	0.3	%	EPE 2012	
Inflation rate	6.31	%	Central Bank 2018	This is the average inflation rate from 2010 to 2017
Electricity tariff from Light for residence	0.62507	R$	Light 2018	
Debt interest rate	1.45	%	Caixa	https://www.financiamentoeconstrucao.com.br/qual-a-taxa-de-juros-cobrada-no-cartao-construcard/
	4.0	%	BNDS	
Equity interest rate	27.28	%		
SELIC (KRf)	6.4	%	Central bank	http://www.bcb.gov.br/htms/selic/selicdiarios.asp
Income tax rate	27.5	%		https://tradingeconomics.com/brazil/personal-income-tax-rate
Average household income per month in Babilônia	1,400	R$	Renato Meirelles 2014 and Survey from Revolusolar 2017	The average monthly income was R$965 in 2014 thus I assume R$1,000 for now as a standard. This number R$1,400 is average monthly income from the 94 interviewees.
Length of residence in Babilônia	44.11	years	Survey from Revolusolar 2017	All of interviewees has been living in Babilônia for more than 10 years and more than half of them has been living more than 40 years

Table 14 Parameter table

6.9. Scenario analysis

6.9.1. Residual value calculation

As early mentioned above, I set 10 years for the project period. It means that it is necessary to think how we will manage with the panels which have 25 years of lifespan. In the case of inverter, it generally lasts 10-15 years thus I will not deal with selling the inverter. Therefore, in the last year of the calculation, I add the amount of costs selling the panels as income for every scenario analysis.

According to IBGE, the producer price index of monthly variation about manufacture of electrical machinery, apparatus and equipment was 1.7% in June 2018. It is difficult to estimate the future cost of solar panels in consideration of rapid price decrease of solar system recent years. In this study, I use 'Straight Line Method' to calculate the depreciation of solar panels. To calculate depreciation under the straight line method, simply divide the number of years of useful life into the depreciable balance (purchase price minus residual value) (Terry Crawford, 2018).

Depreciation = (Purchase Price − Residual Value) / Years of Useful Life

For the initial investment, the whole solar package was considered to buy, not separately each equipment. Thus, to calculate the purchase price, I set the single price of a panel from the market. For example, the 1.28 kWp power generator package includes four panels of 320W and its single price is R$ 949. For the residual value of panels, an investigation into large scale bank financed PV projects indicates that banks use residual values ranging from 15-25% (Joseph McCabe, 2012). I set 15% (R$ 569.4) for the residual value on this analysis and the depreciation is R$ 129.064 = (949*85%) / 25 and the remaining value of selling price after 10 years is R$ 2505.36 (Table 16).

Year	Remaining value, Beginning of year	Depreciation	Remaining value, End of year
1	3796	129.064	3666.936
2	3666.936	129.064	3537.872
3	3537.872	129.064	3408.808
4	3408.808	129.064	3279.744

5	3279.744	129.064	3150.68
6	3150.68	129.064	3021.616
7	3021.616	129.064	2892.552
8	2892.552	129.064	2763.488
9	2763.488	129.064	2634.424
10	2634.424	129.064	2505.36
11	2505.36	129.064	2376.296
12	2376.296	129.064	2247.232
13	2247.232	129.064	2118.168
14	2118.168	129.064	1989.104
15	1989.104	129.064	1860.04
16	1860.04	129.064	1730.976
17	1730.976	129.064	1601.912
18	1601.912	129.064	1472.848
19	1472.848	129.064	1343.784
20	1343.784	129.064	1214.72
21	1214.72	129.064	1085.656
22	1085.656	129.064	956.592
23	956.592	129.064	827.528
24	827.528	129.064	698.464
25	698.464	129.064	569.4

Table 15 Depreciation value of solar panels

- Interest rate 18.86% (Discount rate 18.86%)

For the first calculation, the interest rate 18.86% of Construcard from Caixa is used. Since this applied discount rate is significantly high and the CAPEX/Wp is also high (R$ 6.73/Wp), the result is negative. The IRR of the investment is 9.37%, which is lower than the discount rate 18.86% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ - 3,094. The investment presents itself as inviable, since it presents a negative value. Therefore, the discounted payback of the project cannot be realized in the project period (Figure 44).

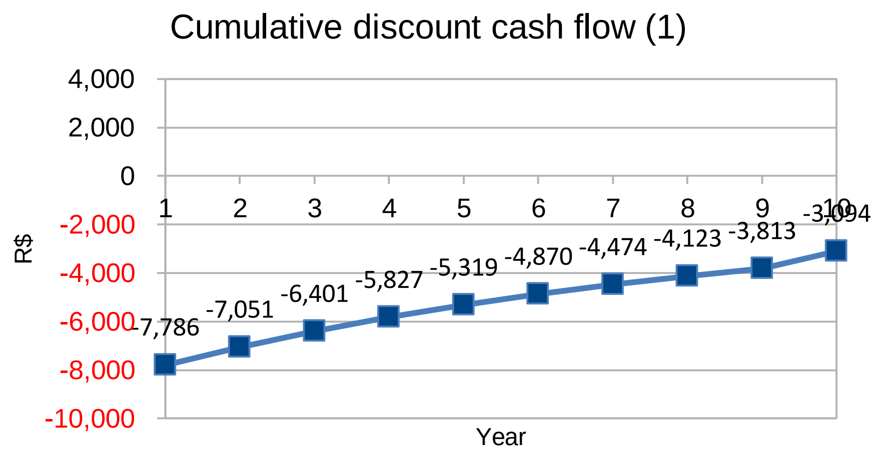


Figure 44 Cumulative discount cash flow (1)

- Interest rate 4% (Discount rate 7.78%)

For the second calculation, the interest rate 4% of Fundo Clima from BNDS is used. By applying the discount rate 7.78% from WACC calculation, the result came out positive. For this model, the resident pays 20% of total expenditure, which is R$ 1,723. The IRR of the investment is 9.37% is same to the first calculation since the cash flow is not changed. However, it is higher than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ 766. The investment presents itself as viable, since it presents a positive value. Therefore, the discounted payback of the project reaches 9 years and 7.2 months, which is the time the project will require to pay the investment and from which it will begin to generate profits (Figure 45).

In addition, since the interest rate from Caixa is much less viable for this study, I will apply the interest rate from BNDES for all the further calculation. Also, the upcoming models are based on this model but some elements will be adjusted to present the different result.

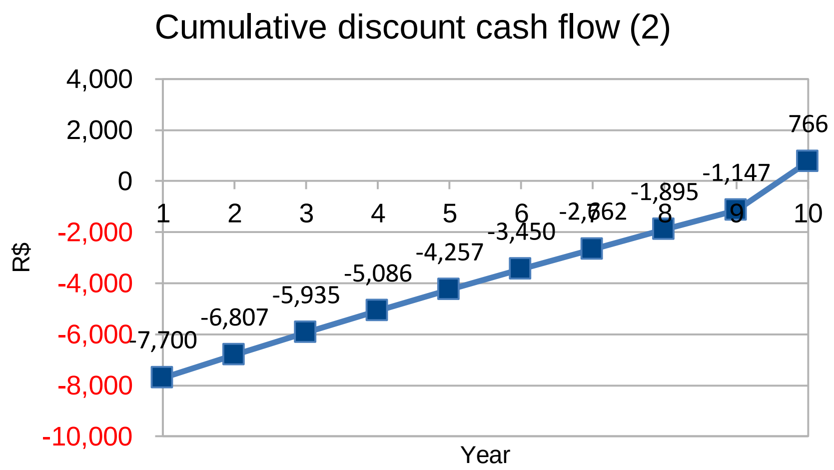


Figure 45 Cumulative discount cash flow (2)

6.9.2. Tariff and subsidy change

- 10% of tariff increase

As mentioned above, the average inflation rate on this study is 6.31%. However, considering the 6.7.1, the consumer price index in Rio de Janeiro has higher increase than the others, I will assume the electricity tariff increase in Rio de Janeiro is higher than the national inflation rate and set 10% as an example.

<table>
<tr><th>Year</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td rowspan="3">Electricity price (R$/kWh)</td><td>0.62507</td><td>0.6645</td><td>0.7064</td><td>0.7510</td><td>0.7984</td><td>0.8487</td></tr>
<tr><td rowspan="2">Inflation rate 6.31%</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>0.9023</td><td>0.9592</td><td>1.0198</td><td>1.0841</td><td>1.1525</td></tr>
</table>

Year	0	1	2	3	4	5
Electricity price (R$/kWh)	0.62507	0.6875	0.7563	0.8319	0.9151	1.0066

		6	7	8	9	10
	Tariff increase rate 10%	1.1073	1.2180	1.3398	1.4738	1.6212

Table 16 The comparison of electricity price applying different increase rate

This table 17 shows the comparison of electricity price applying different rate. With tariff increase rate 10%, the price rose up more rapidly and this tendency supports to bring more positive result for implementing solar energy projects.

The IRR of the investment is 12.81%, which is higher than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ 2,638. The investment presents itself as viable, since it presents a positive value. Therefore, the discounted payback of the project reaches 8 years and 7.5 months and this is faster than the previous calculation (Figure 46). In conclusion, rapid increase rate of tariff and the consequential more expensive cost are one of the main incentives to bring more investment for solar energy projects.

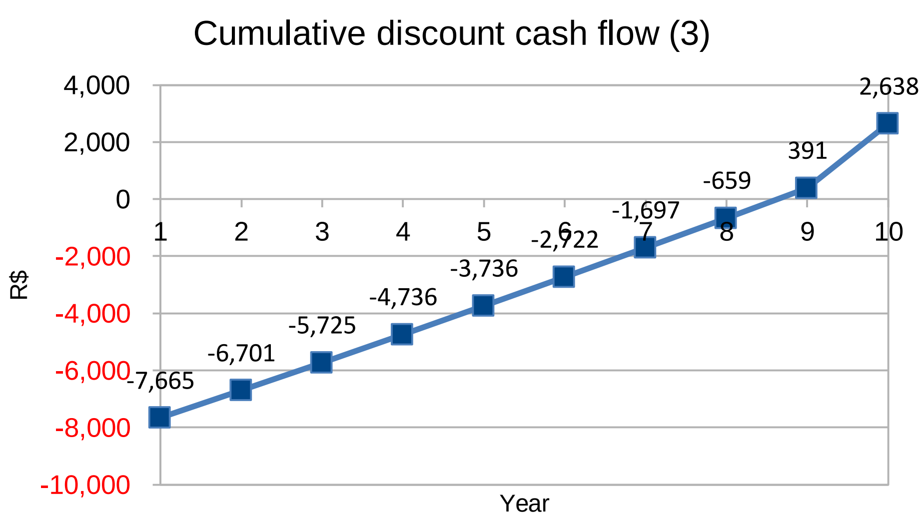


Figure 46 Cumulative discount cash flow (3)

- Lower social tariff

On the other hand, more subsidy for social tariff could make this project less attractive bringing out the lower electricity cost for residences in favelas. This part is profoundly connected with the political stance of each government. At this moment, the presidential election in Brazil is coming soon in a few months and the subsidy for the vulnerable social group would be affected by the new government.

Year	0	1	2	3	4	5
Electricity price (R$/kWh)	0.62507	0.6645	0.7064	0.7510	0.7984	0.8487
	Inflation rate 6.31% with current social tariff 0.62507	6	7	8	9	10
		0.9023	0.9592	1.0198	1.0841	1.1525

Year	0	1	2	3	4	5
Electricity price (R$/kWh)	0.41672	0.4430	0.4709	0.5006	0.5322	0.5658
	Inflation rate 6.31% with lowered social tariff 0.41672	6	7	8	9	10
		0.6015	0.6395	0.6798	0.7227	0.7684

Table 17 The comparison of electricity price by lowering the social tariff subsidy

For this calculation, I used the social tariff 0.41672, which is the current social tariff for the consumption from 31 to 100 kWh to assume that this tariff would be applied for all the amount of consumption. The same inflation 6.31% was applied to compare with the current social tariff 0.62507, which is a tariff for the consumption from 101 to 220 kWh currently. The result shows that lowered electricity cost and the gap is significantly huge (Table 18).

CPI study shows that the Northeast Region of Brazil has the highest annual solar radiation levels, as well as lower electricity tariffs, partly due to subsidies. This policy design makes the price of electricity in the region artificially low, reducing the profitability of investments in photovoltaic solar panels. The price variation between localities ultimately concentrates the market for distributed solar generation in the

Southeast Region, which has the highest electricity tariff in Brazil (Elysha Davila, 2017).

In conclusion, the IRR of the investment is significantly low 2.7%, which is lower than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ - 2,292. The investment presents inviable, since it presents a negative value. Therefore, the discounted payback of the project cannot be realized in the project period (Figure 47).

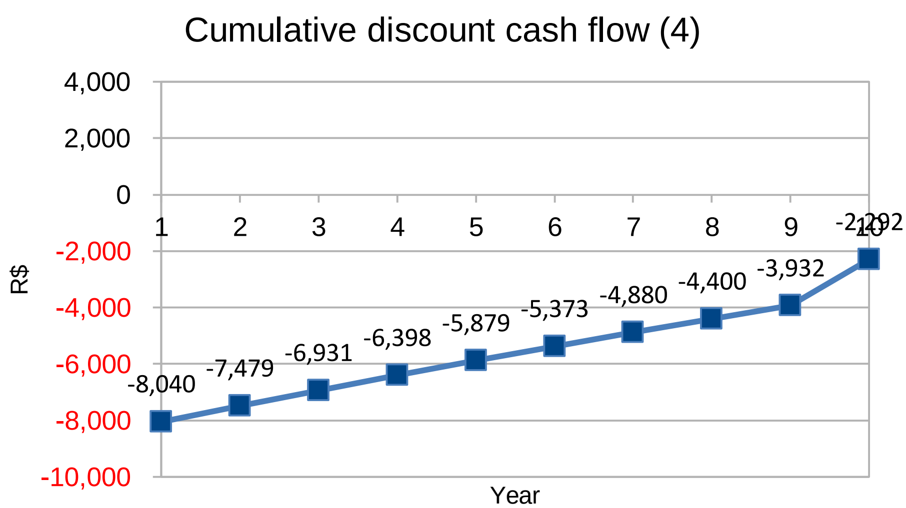


Figure 47 Cumulative discount cash flow (4)

6.9.3. Cooperative models

The cooperative model is based on the theory of economies of scale. The previous models above were calculated only for one household. However, for cooperative models, more participants join for the same objective and everyone takes the responsibility and benefit together. One of the best advantages of this model is that it can reduce not only interest rate but also the initial equipment cost.

System size has a significant and beneficial impact on rooftop and ground-mount system prices. Large PV systems not only better amortize fixed project overhead expenses—they also improve installer efficiencies and drive more efficient supply chain strategies. Figure 48 summarizes the modeled price benefits of increased system size across market segments. There are significant economies of scale within and across market segments, with diminishing returns as system size increases within each market segment (NREL, 2012).

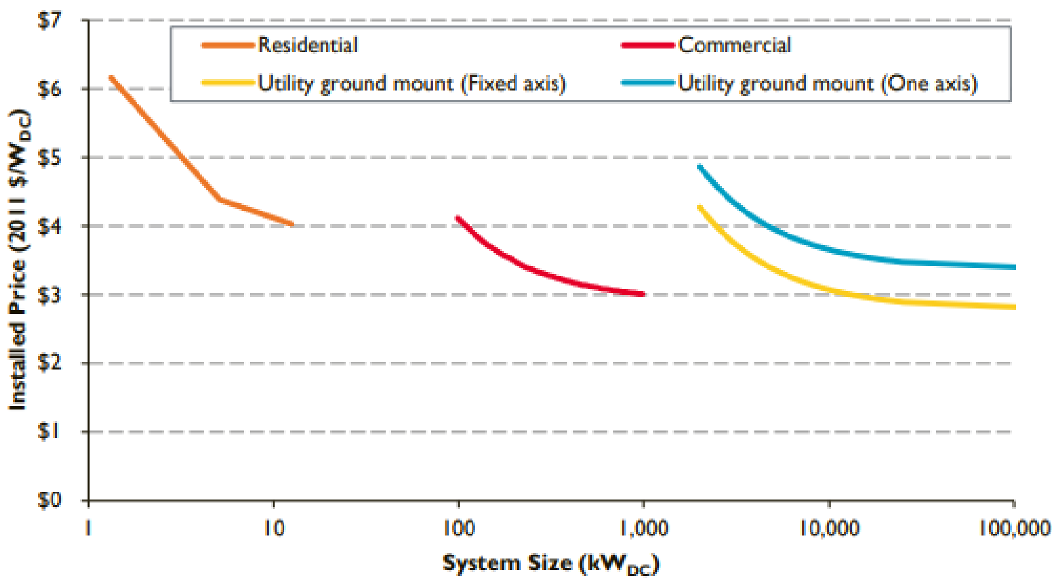


Figure 48 Economy-of-scale benefits: residential and commercial rooftop, ground-mount utility scale

(Source: (NREL, 2012))

For this models, different costs and size are applied. Firstly, the maximum potential of power generator would be higher as more household joins and it makes the cost per unit decreases. Since it is not about the single household, I don't use the result of the America do Sol. Instead of it, I assume that there are 3 cooperative options – 5, 10, 20 households. Then, I multiply the monthly average electricity consumption per household – 195kWh with the number of households to calculate the expected electricity demand. The same discount rate 7.78% is used for this model too.

- 5 households

Approximately, 1,000 kWh per month are consumed by 5 households and the power generator 8.58 KWp can produce 1,171 kWh[5]. The initial investment is R$ 39,082 including the adjusted delivery and labour costs. CAPEX/Wp decreases to R$ 4.56/Wp. This package has 26 panels which are assumed to sell after 10 years. The amount of equity is R$ 7,816.38 and each household is supposed to invest R$ 1,563.28 with their saving for the first year.

The IRR of the investment is 24.47%, which is much higher than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ 42,134. The investment presents itself as viable, since it presents a positive value. Therefore, the discounted payback of the project reaches 5 years and this is faster than the previous calculation (Figure 49). Reaching the payback period in 5 years has a significant importance for this study since I target the low income class. Compared to the conventional solar energy investment planning for 25 years, which is almost not feasible for residence in favelas, shortening the payback period as much as can be one of the key factors of this study in order to persuade them to join to this project to guaranty for their investment.

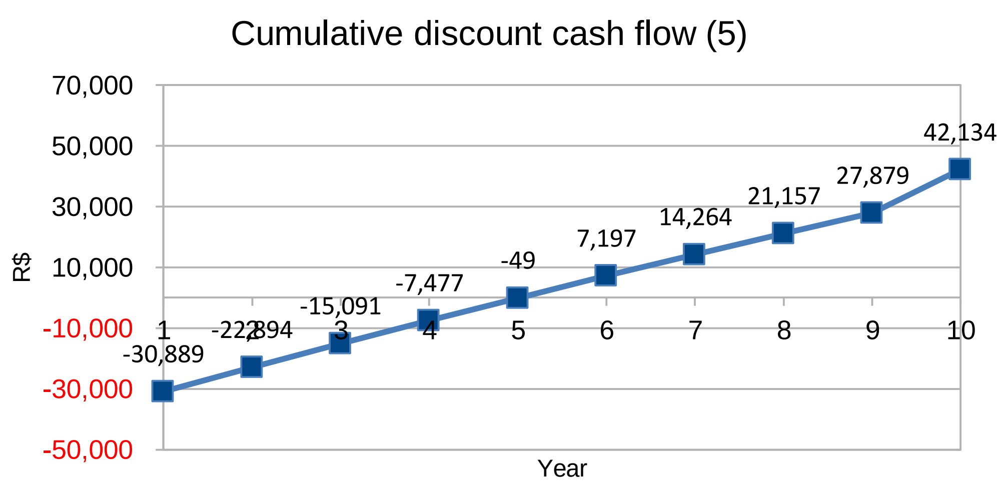


Figure 49 Cumulative discount cash flow (5)

[5] https://www.portalsolar.com.br/loja/gerador-de-energia-trapezoidal-aldo-solar-gef-8580fz-858kwp-fronius-primo-mono-220v-canadian?___SID=U

- 10 households

Approximately, 2,000 kWh per month are consumed by 10 households and the power generator 14.3 kWp can produce 1,952 kWh[6]. The initial investment is R$ 61,038 including the adjusted delivery and labour costs. CAPEX/Wp decreases to R$ 4.27/Wp. This package has 44 panels which are assumed to sell after 10 years. The amount of equity is R$ 12,207.58 and each household is supposed to invest R$ 1,220.76 with their saving for the first year.

The IRR of the investment is 26.45%, which is much higher than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ 75,006. The investment presents itself as viable, since it presents a positive value. Therefore, the discounted payback of the project reaches 4 years 7.8 months and this is a little faster than the previous calculation of 5 households model (Figure 50).

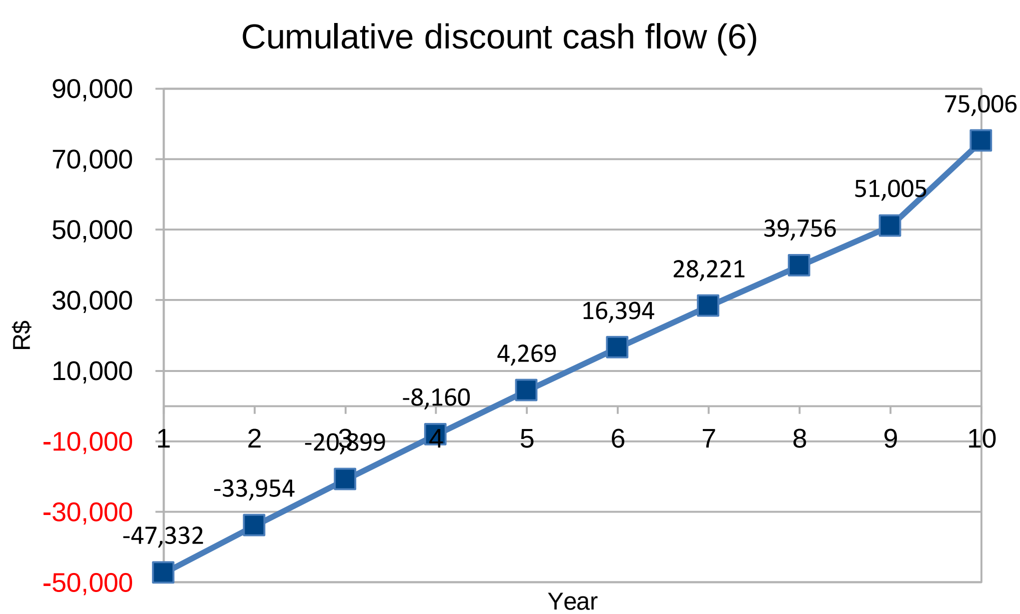


Figure 50 Cumulative discount cash flow (6)

[6] https://www.portalsolar.com.br/loja/gerador-de-energia-ondulada-55cm-aldo-solar-gef-14300fz-143kwp-fronius-symo-trif-380v-byd?___SID=U

- 20 households

Approximately, 4,000 kWh per month are consumed by 20 households and the power generator 29.7 kWp can produce 4,054 kWh[7]. The initial investment is R$ 111,473 including the adjusted delivery and labour costs. CAPEX/Wp decreases to R$ 3.75/Wp. This package has 90 panels which are assumed to sell after 10 years. The amount of equity is R$ 22,294.58 and each household is supposed to invest R$ 1,114.73 with their saving for the first year.

The IRR of the investment is 30.58%, which is much higher than the discount rate 7.78% that allows the cash flows to be equal to 0. The NPV of the investment reaches R$ 172,396. The investment presents itself as viable, since it presents a positive value. Therefore, the discounted payback of the project reaches 4 years and this is a shortest payback period between every model on this study (Figure 51).

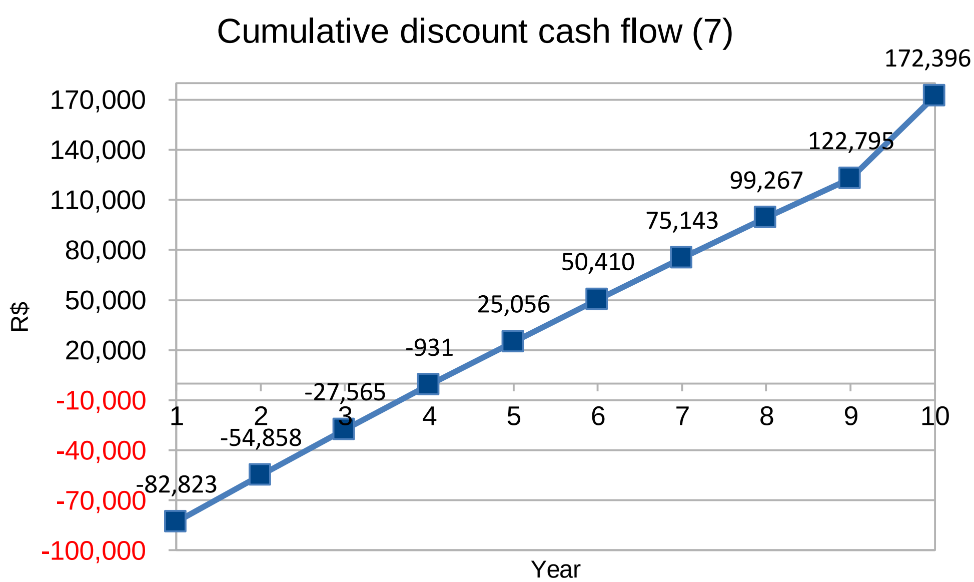


Figure 51 Cumulative discount cash flow (7)

[7] https://www.portalsolar.com.br/loja/gerador-de-energia-colonial-aldo-solar-gef-29700fc-297kwp-fronius-eco-trif-380v-canadian?___SID=U

7. DISCUSSION

The most critical points of this study are the viability of financing, and current tax issue. The first critical point is to consider the fact that the target of this study is residences in favelas with low income and they have been excluded by the society for a long time. Without the credible and suitable funding and financing, it would be difficult to implement this project. On the economic analysis chapter, I considered two financial resources – Caixa and BNDS. Above this, there are financing from private banks such as Santander and FNE Sol program from Banco do Nordeste. Although FNE Sol program finances for Northeastern states and the North of Minas Gerais and Espirito Santo, this type of finance can be considered as a model for projects in the other area of Brazil.

Additionally, collaborating with Light could be an option. From the interviews with Professor Alexandre Salem Szklo from Universidade Federal do Rio de Janerio and Reinaldo Castro Souza from Pontifica Universidade Catolica do Rio de Janeiro, they highlighted that Light has an obligation to invest 1% of the total profit for R&D, which is almost R$ 1.2 – 1.5 million. They said it would be interesting if Light could invest for this type of solar energy project in order to solve the electricity theft issue. However, since the national economic crisis also aggravated the situation of Light and Light cut down a lot budgets for social projects, it is necessary to have a concrete project plan to persuade Light.

The second critical point is the tax issue for distributed solar generation. To engage more intention for distributed solar PV, the methods that the government can take into account are tax deduction from the bill and subsidy for equipment. However, in the case of tax deduction from the bill, firstly we have to start to produce the energy to get the benefit – which is tax deduction. But on condition that dwellers in favelas do not have savings initially to join to this market to have this tax deduction benefit, this cannot be an attractive benefit for them. Therefore, tax deduction is not the incentive for distributed solar PV expansion for this target.

Moreover, even with this tax deduction, there is a weak point. The type of taxes which are deducted are only the Federal ones – PIS and COFINS. However, the State tax (ICMS) is not applied for this. It means that with the current net metering system, the State government imposes on ICMS for even the amount of electricity which are generated by solar PV.

PV feasibility is firstly found in sites where consumers' power tariffs are higher than Brazil's average. Therefore, the strategic plan considering the current tariff level would help to proliferate solar PV. Moreover, to guarantee for public/private banks to set the low interest rate for credit for residences in favelas could be an engaging option in order to lower the barrier to entry for them.

8. CONCLUSION AND OUTLOOK

There have been numerous debates about favelas in Rio de Janeiro, especially related to the public health, education, and sanitation issues, due to their significant and complex impacts to the rest of the Brazilian society for a long time. However, since renewable energy is a relatively new concept, there are not many studies yet considering the possibility of this innovative technology in favelas. Therefore, this study investigated the potential role of solar PV in favelas in Rio de Janeiro, Brazil and sought for the proper financing alternatives in Babilônia.

Brazil has reached a cumulative installed solar power of around 1,099.6 MW, of which 935.3 MW is represented by large-scale solar plants, and 164.3 MW by distributed generation PV power generators (up to 5 MW). The solar power generation has been rapidly increasing and because of its mid-latitude geographical location, Brazil is privileged with abundant solar radiation, where the sun rises on average 280 days a year. With this advantage, the price of solar system for end customer has been dramatically decreasing last years.

With Resolution 482/2012, the general conditions for the access of microgeneration to the electric energy distribution systems, and the electric energy compensation system were implemented. This net metering system made possible to send excess power from distributed generation to the Brazilian grid, with the final consumer being rewarded later in the form of credits (discounts) in future bills. This law enforcement was the first initiative to encourage solar PV expansion in Brazil.

The electricity demand and consumption are profoundly related with the consumers' behavior and this is also connected with the lack of knowledge by dwellers in favelas about the energy efficiency. Although the great majority of residences in Babilônia claim to be able to afford the payment, they say that the payment is made with a lot of "difficulty". They also believe that the electricity bill has increased in recent years a lot. The evident opinion about the electricity bill by Light was many of dwellers doubt about the correctness of digital clock after its regularization and they have lots of distrust with Light.

The total electricity consumption of 58-60 households in Babilônia were 138,379kWh in 2017. The average per month were 11,532kWh in total and 195kWh per household. With the cost benefit calculation with different scenario analysis, I could draw following conclusions.

- By applying the interest rate 4% of Fundo Clima from BNDS and the discount rate 7.78% from WACC calculation, the result came out positive. For this model, the resident pays 20% of total expenditure, which is R$ 1,723. The IRR of the investment is 9.37%, it is higher than the discount rate 7.78%. The NPV of the investment reaches R$ 766. The investment presents itself as viable and the discounted payback of the project reaches 9 years and 7.2 months.
- With the 10% of electricity tariff increase and the consequential more expensive cost are one of the main incentives to bring more investment for solar energy projects. The IRR of the investment is 12.81%, which is higher than the discount rate 7.78%. The NPV of the investment reaches R$ 2,638. The investment presents itself as viable and the discounted payback of the project reaches 8 years and 7.5 months.
- More subsidy for social tariff could make this project less attractive bringing out the lower electricity cost for residences in favelas. With the lower social tariff showed that the IRR of the investment is significantly low 2.7%, which is lower than the discount rate 7.78%. The NPV of the investment reaches R$ -2,292. The investment presents inviable and the discounted payback of the project cannot be realized in the project period.
- With 5 households of cooperative model, the IRR of the investment is 24.47%, which is much higher than the discount rate 7.78%. The NPV of the investment reaches R$ 42,134. The investment presents itself as viable and the discounted payback of the project reaches 5 year.
- With 10 households of cooperative model, the IRR of the investment is 26.45%, which is much higher than the discount rate 7.78. The NPV of the investment reaches R$ 75,006. The investment presents itself as viable and the discounted payback of the project reaches 4 years 7.8 months and this is a little faster than the previous calculation of 5 households model.
- With 20 households of cooperative model, the IRR of the investment is 30.58%, which is much higher than the discount rate 7.78%. The NPV of the

investment reaches R$ 172,396. The investment presents itself as viable and the discounted payback of the project reaches 4 years and this is a shortest payback period between every model on this study.

This result shows that the importance of economies of scale. Also, using cooperative models make the residences be part of the project, which is an essential point to implement a project in favelas.

The illegal electricity use is not an issue that Light alone should deal with but the government's support is necessary as well. In the end, this issues should be discussed with the public and the government to have more attention from different stakeholders because energy poverty is a critical issue for everyone.

Having access to affordable and safe electricity is one of the main necessities for residences in favelas these days and it is a golden opportunity for the Brazilian government and tenants to utilize the solar energy which they abundantly have and which is environmentally friendly.

The Brazilian government should consider energy demand-side factors such as electricity tariff, salary and population to improve the market development for distributed solar generation. Therefore, it is essential to make strategies that promote renewable energy with the combination of economic development approaches for the most vulnerable areas. What I have realized from this study is that the natural resources alone are not enough for the expansion of solar PV in Brazil. As a result, developing solar PV in Brazil's energy background will be determined by policies which lower the barrier to entry for not only high income class but also low income class with appropriate finance support.

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Appendix A. Questionário Babilônia RevoluSolar

Introdução e Objetivo da Pesquisa

O objetivo dessa pesquisa é entender quantos são os custos em Kwh/mês por domicílio ou comércio da Babilônia. Por exemplo, sabemos que há casos nos quais o morador paga uma parte da conta e outra não, ou simplesmente não paga nada à fornecedora de energia elétrica, porque não tem condições econômicas, ou seja, casos nos quais a renda do morador não é suficiente. Temos muita tranquilidade para tratar desse assunto, porque sabemos que nossa constituição estipula um teto para gastos com energia elétrica, porque ela é ao mesmo tempo um direito e um dever. Direito ao fornecimento da eletricidade pelo Estado, mas também dever do consumidor pagar pelo serviço à prestadora. Estamos tentando calcular um preço justo. Para isso precisamos entender as possibilidades de pagamento dos moradores, o que fica mais confortável para o bolso do morador. Queremos saber se na sua casa tem ou teve algum problema assim e se sim e como é ou foi resolvido. No caso de ter gato, gostaríamos de saber sobre a sua disponibilidade orçamentária para pagar um preço que considere justo, a vantagem seria sair da ilegalidade e ainda contribuir para o uso eficiente (e sustentável) da energia elétrica. Como? Através de descontos a serem gerados através da participação dos moradores como membros da cooperativa de energia solar que está em fase embrionária. Sendo assim, essa pesquisa pretende avaliar a viabilidade da criação dessa cooperativa na favela a ser implementada a longo prazo a partir de auto-gestão, ou seja, a partir da colaboração e engajamento de grande parte dos moradores da comunidade na Babilônia.

A gente tem uma série de perguntas sobre o tema. Se você não se sente a vontade de respondera qualquer delas, não tem problema nenhum.

Os dados que você compartilha são confidenciais. Aqui a gente tem um termo de consentimento para assegurar a confidencialidade de seus dados e guardar com a gente a sua autorização para o uso das informações preservando o seu anonimato.

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Nome:

Endereço:

Número de cliente na Light:

Código questionário:

(p.ex:D1)

Código de localização no morro da Babilônia:

(p.ex:HAB2; Buraco)

Consumo de energia elétrica

Aqui o morador responde sobre os aparelhos domésticos que tem e os quais usa frequentemente:

	Aparelhos	Quant.	P(W)	Tempo diário(mín)	Dias no mês	Consumo (kWh)	Quanto tempo esse aparelho?
1	TV						
2	Lavadora de roupa						
3	Ventilador						
4	Lâmpada incandescente						
5	Lâmpada florescente						
6	Lâmpada Led						
7	Chuveiro elétrico						
8	Geladeira						
9	Ar.condicionado						
10	Computador						

Gastos com luz (energia elétrica)

1) Quanto é a média da sua conta de luz por mês em reais? Poderia nos mostrar algumas de suas contas?

2) Consegue pagar as contas?

3) Já atrasou alguma vez o pagamento?

4) Já precisou parcelar a conta alguma vez com Light?

5) A média de preço da sua conta de luz mudou nos últimos anos?

1.( )Aumentou 2.( )Diminuiu 3.( )Igual

6) Se sim, de quanto foi a mudança?

7) Quando ela ocorreu?

8) Por que o Sr (a). acha que mudou?

9) Se aumentou, como fez ou faz para reduzir os custos?

10) O(a) sr(a) costumavam pagar a conta de luz antes do processo de regularização do serviço pela Light em 2010?

11) Se sim, de quanto era?

12) O que o(a) Sr (a) acha sobre a questão dos gatos?

13) Continuam pagando a conta normalmente?

14) Conhece alguém que "está no gato"?

15) O(a) sr (a) lembra-se quantas vezes faltou luz no período de 2016 a 2017?

16) Por quanto tempo?

17) O problema foi solucionado pela companhia de energia elétrica ou pelos moradores?

18) O seu relógio de marcação funciona corretamente?

19) O (a) Sr (a) tem acesso ao medidor digital?

20) Em comparação com o serviço de medição analógico, qual o(a) sr(a). prefere?

21) O(a) Sr(a) recebe algum benefício do governo para descontos na conta de luz, como por exemplo, direito à TSEE (Tarifa Social de Energia Elétrica)?

22) Tem ou já teve o cartão do projeto Light Recicla?

23) Se sim, quanto já conseguiu economizar com esse desconto?

24) O que achou dessa iniciativa da Light?

25) O (a) Sr (a) tem hábito de separar os resíduos orgânicos dos materiais recicláveis?

Dimensão Social

Quanto tempo o (s)sr(a) mora na Babilônia?

Quantas pessoas moram / trabalham na sua casa?

Você é proprietário ou inquilino desta casa?

Em que o (a) Sr.(a) trabalha?

Essa pergunta é para que possamos calcular qual é a porcentagem da sua renda destinada ao consumo de energia elétrica, considerando igualmente a renda de um trabalho formal e/ou informal, ok?

Qual é (em média) a sua renda mensal?

Seu custo de vida mudou nos últimos anos?

Se sim, quanto?

Quando mudou?

Por que acha que mudou?

Casa

Sua casa funciona como:

0.(   ) residência   1.(   )comércio/empresa   2.(   )os dois

O (a) sr(a) trabalha em casa?

Quantas horas por dia passa trabalhando em casa?

Comparando com o período anterior à regularização, fica mais ou menos em casa atualmente

Se esse hábito mudou, quando foi exatamente que isso aconteceu?

Por que precisou mudar os hábitos?

Comércio

Que tipo de trabalho o(a) sr (a) exerce?

Quantas pessoas trabalham neste empreendimento?

O(a) sr(a) tem ou já teve CNPJ ou MEI?

A empresa ainda funciona?

Depois da formalização do serviço de energia elétrica na favela, o preço na conta do seu empreendimento mudou?

Quanto tempo fica no comércio diariamente?

Quantas vezes por semana?

A que o(a) sr(a) atribui essa mudança de preço na conta?

Fica mais ou menos tempo no trabalho do que ficava antes da regularização do serviço?

d) Dimensão sócio-técnica sobre energia solar e criação de cooperativa

Revolusolar

O (a) Sr(a) tem algum conhecimento sobre energia solar? Qual?

Já ouviu falar da RevoluSolar? O que ouviu?

Gostaria de fazer parte?

Se sim, de que maneira poderia de colaborar?

Em caso de trabalho voluntário ficaria interessado em participar? Fazendo o que?

Em caso de trabalho remunerado ficaria interessado em participar? Fazendo o que?

Indicaria amigos, parentes e vizinhos para fazer parte? O que eles fariam?

Energia Solar

Compraria eletricidade com Revolusolar se houvesse garantia de que os créditos seriam distribuídos para os membros moradores da Babilônia?

Quanto estaria disposto a pagar?

Esse valor é o mesmo, maior ou menor que o pagamento da conta atual?

Cooperativa

O (a) sr (a) sabe o que é um cooperativa?

Poderia explicar em poucas palavras?

Se fosse para formar uma cooperativa, o (a) sr(a) teria interesse em se tornar membro?

Se sim, quanto estaria disposto a pagar para entrar como membro (pagando apenas uma vez)?

Quais serviços a cooperativa deveria oferecer na sua opinião?

Telhado

Qual tipo de telhado tem em sua casa e/ ou comércio? Qual material?

Qual é o tamanho de telhado? (levar o medidor)

Tem sobreamento por perto, por exemplo, árvore, prédio ou outro bloqueador solar?

Fica em qual lado do morro("bairro"da Babi)?

Appendix B. Cost benefit analysis results

- Interest rate 18.86% (Discount rate 18.86%)

GENERATION

Power generator	Wp	1,280	Generated energy per month	138
Generated energy	kWh/year	1,654	delivery	300
Annual lose	% a.a.	1.0%	labour	180
Finance			generator package	7,352.74
Initial investment	R$	8,616	4 panels	3796
Equipment investment (CAPEX)	R$/Wp	6.73		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	18.86%		
Financing				
Total amount	%	100%	R$ 8,616.01	
Amount financed	%	100.0%	R$ 8,616.01	
Interests on financing	% a.a.	18.86%	1.45%	% a.m.
Interests on financing	% a.m	1.45%		

Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			1,654	1,637	1,621	1,604	1,588	1,571	1,555	1,538	1,522	1,505

Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy												
Electricity price (R$/kWh)		0.625	0.664511917	0.706442619	0.751019	0.798408	0.84878803	0.902347	0.959285	1.019815	1.084166	1.152577
Total generated electricity price (R$)			1099.109356	1156.778525	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	1734.8
Income												
Total generated electricity price (R$)			1099.109356	1156.778525	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	1734.8
selling panels												2505.36
Total income			1099.109356	1156.778525	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	4240.16
Expenses												
Initial investment		-8,616										
Variable costs												
Operating & Maintenance cost			-86.16014	-91.59684483	-97.3766	-103.521	-110.0532491	-116.998	-124.38	-132.229	-140.572	-149.442
Insurance			-25.848042	-27.47905345	-29.213	-31.0563	-33.01597472	-35.0993	-37.314	-39.6686	-42.1717	-44.8327
Total expenses	-10,114	-8,616	-112	-119	-127	-135	-143	-152	-162	-172	-183	-194
Result												
Cash flow		-8,616	987	1,038	1,091	1,146	1,205	1,266	1,330	1,397	1,467	4,046
Cumulative cash flow		-8,616	-7,629	-6,591	-5,500	-4,354	-3,149	-1,884	-554	843	2,310	6,356

Interest rate q+1			119%	119%	119%	119%	119%	119%	119%	119%	119%	119%
Multiplier from interest load		1	0.84132593	0.70782932	0.595515	0.501022	0.421523091	0.354638	0.298366	0.251023	0.211192	0.177682
Contribution to NPV		-8,616	830.4738128	734.5163443	649.564	574.3625	507.7998095	448.8901	396.7593	350.6327	309.8235	718.8798
Net Present Value (NPV)		-3,094										
Cumulative discount cash flow - discounted payback			-7,786	-7,051	-6,401	-5,827	-5,319	-4,870	-4,474	-4,123	-3,813	-3,094

- Interest rate 4% (Discount rate 7.78%)

GENERATION				
Power generator	Wp	1,280	Generated energy per month	138
Generated energy	kWh/year	1,654	delivery	300
Annual lose	% a.a.	1.0%	labour	180
Finance			generator package	7,352.74
Initial investment	R$	8,616	4 panels	3796
Equipment investment (CAPEX)	R$/Wp	6.73		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 8,616.01	
Own equity	%	20.0%	R$ 1,723.20	
Amount financed	%	80.0%	R$ 6,892.81	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
S	20.00%
B/S	4.00
B + S	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

Cash flow (profits			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			1,654	1,637	1,621	1,604	1,588	1,571	1,555	1,538	1,522	1,505
Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy												
Electricity price (R$/kWh)		0.625	0.664511917	0.7064426	0.751019	0.798408	0.84878803	0.902347	0.959285	1.019815	1.084166	1.152577
Total generated electricity price (R$)			1099.109356	1156.7785	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	1734.8
Income												
Total generated electricity price (R$)			1099.109356	1156.7785	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	1734.8
Selling panels												2505.36
Total income			1099.109356	1156.7785	1217.349	1280.958	1347.747734	1417.866	1491.466	1568.71	1649.763	4240.16
Expenses												
Initial investment		-8,616										
Variable costs												
Operating & Maintenance cost			-86.16014	-91.59684	-97.3766	-103.521	-110.0532491	-116.998	-124.38	-132.229	-140.572	-149.442

Insurance			-25.848042	-27.47905	-29.213	-31.0563	-33.01597472	-35.0993	-37.314	-39.6686	-42.1717	-44.8327
Total expenses	-10,114	-8,616	-112	-119	-127	-135	-143	-152	-162	-172	-183	-194
Result												
Cash flow		-8,616	987	1,038	1,091	1,146	1,205	1,266	1,330	1,397	1,467	4,046
Cumulative cash flow		-8,616	-7,629	-6,591	-5,500	-4,354	-3,149	-1,884	-554	843	2,310	6,356
Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.798802	0.741171	0.687698817	0.638084	0.592049	0.549335	0.509703	0.47293
Contribution to NPV		-8,616	915.885796	893.37177	871.3007	849.6647	828.4559865	807.667	787.2902	767.3182	747.7438	1913.419
Net Present Value (NPV)		766										
Cumulative discount cash flow - discounted payback			-7,700	-6,807	-5,935	-5,086	-4,257	-3,450	-2,662	-1,895	-1,147	766

- 10% of tariff increase

GENERATION				
Power generator	Wp	1,280	Generated energy per month	138
Generated energy	kWh/year	1,654	delivery	300
Annual lose	% a.a.	1.0%	labour	180
Finance			generator package	7,352.74
Initial investment	R$	8,616.014	4 panels	3796
Equipment investment (CAPEX)	R$/Wp	6.73		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 8,616.01	
Own equity	%	20.0%	R$ 1,723.20	
Amount financed	%	80.0%	R$ 6,892.81	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
S	20.00%
B/S	4.00
B + S	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	28%

Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			1,654	1,637	1,621	1,604	1,588	1,571	1,555	1,538	1,522	1,505

Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy												
Electricity price (R$/kWh)		0.625	0.687577	0.7563347	0.83196817	0.91516499	1.006681486	1.10734963	1.2180846	1.33989306	1.473882363	1.6212706
Total generated electricity price (R$)			1137.259234	1238.4753	1348.562	1468.28128	1598.458794	1739.989	1893.84066	2061.06276	2242.790874	2440.25398
Income												
Total generated electricity price (R$)			1137.259234	1238.4753	1348.562	1468.28128	1598.458794	1739.989	1893.84066	2061.06276	2242.790874	2440.25398
Selling panels												2505.36
Total income			1137.259234	1238.4753	1348.562	1468.28128	1598.458794	1739.989	1893.84066	2061.06276	2242.790874	4945.61398
Expenses												
Initial investment		-8,616.014										
Variable costs												
Operating & Maintenance cost			-86.16014	-91.59684	-97.376606	-103.52107	-110.0532491	-116.99761	-124.38016	-132.22855	-140.572167	-149.44227
Insurance			-25.848042	-27.47905	-29.212982	-31.056321	-33.01597472	-35.099283	-37.314047	-39.668564	-42.1716502	-44.832681
Total expenses	-10,114	-8,616.014	-112.008	-119.076	-126.590	-134.577	-143.069	-152.097	-161.694	-171.897	-182.744	-194.275

Result												
Cash flow		-8,616	1,025	1,119	1,222	1,334	1,455	1,588	1,732	1,889	2,060	4,751
Cumulative cash flow		-8,616	-7,591	-6,471	-5,249	-3,916	-2,460	-872	860	2,749	4,809	9,560
Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.79880167	0.74117135	0.687698817	0.63808411	0.59204891	0.54933497	0.509702659	0.47292966
Contribution to NPV		-8,616	951.2833138	963.7056	976.113608	988.503108	1000.869686	1013.20873	1025.51543	1037.78475	1050.011462	2247.04917
Net Present Value (NPV)		2,638										
Cumulative discount cash flow - discounted payback			-7,665	-6,701	-5,725	-4,736	-3,736	-2,722	-1,697	-659	391	2,638

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- Lower social tariff

GENERATION				
Power generator	Wp	1,280	Generated energy per month	138
Generated energy	kWh/year	1,654	delivery	300
Annual lose	% a.a.	1.0%	labour	180
Finance			generator package	7,352.74
Initial investment	R$	8,616	4 panels	3796
Equipment investment (CAPEX)	R$/Wp	6.73		
Electricity tariff from Light	R$/kWh	0.417		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 8,616.01	
Own equity	%	20.0%	R$ 1,723.20	
Amount financed	%	80.0%	R$ 6,892.81	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
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Unleveraged Beta	0.47
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Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			1,654	1,637	1,621	1,604	1,588	1,571	1,555	1,538	1,522	1,505
Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%

Economy												
Electricity price (R$/kWh)		0.417	0.443015032	0.4709693	0.500687	0.532281	0.565867739	0.601574	0.639533	0.679888	0.722789	0.768397
Total generated electricity price (R$)			732.7512931	771.19802	811.5792	853.9859	898.5128637	945.2589	994.3268	1045.823	1099.86	1156.552
Income												
Total generated electricity price (R$)			732.7512931	771.19802	811.5792	853.9859	898.5128637	945.2589	994.3268	1045.823	1099.86	1156.552
Selling panels												2505.36
Total income			732.7512931	771.19802	811.5792	853.9859	898.5128637	945.2589	994.3268	1045.823	1099.86	3661.912
Expenses												
Initial investment		-8,616										
Variable costs												
Operating & Maintenance cost			-86.16014	-91.59684	-97.3766	-103.521	-110.0532491	-116.998	-124.38	-132.229	-140.572	-149.442
Insurance			-25.848042	-27.47905	-29.213	-31.0563	-33.01597472	-35.0993	-37.314	-39.6686	-42.1717	-44.8327
Total expenses	-10,114	-8,616	-112	-119	-127	-135	-143	-152	-162	-172	-183	-194
Result												
Cash flow		-8,616	621	652	685	719	755	793	833	874	917	3,468
Cumulative cash flow		-8,616	-7,995	-7,343	-6,658	-5,939	-5,183	-4,390	-3,558	-2,684	-1,766	1,701

Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.798802	0.741171	0.687698817	0.638084	0.592049	0.549335	0.509703	0.47293
Contribution to NPV		- 8,616	575.9589933	561.42047	547.1708	533.2049	519.5176976	506.1041	492.9592	480.0783	467.4565	1639.948
Net Present Value (NPV)		- 2,292										
Cumulative discount cash flow - discounted payback			-8,040	-7,479	-6,931	-6,398	-5,879	-5,373	-4,880	-4,400	-3,932	-2,292

- Cooperative models – 5 households

Power generator	Wp	8,580	Generated energy per month	1,171
Generated energy	kWh/year	14,052	delivery	600
Annual lose	% a.a.	1.0%	labour	240
Finance			generator package	34,689.00
Initial investment	R$	39,082	26 panels	24674
Equipment investment (CAPEX)	R$/Wp	4.56		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 39,081.90	
Own equity	%	20.0%	R$ 7,816.38	each household R$ 1,563.28
Amount financed	%	80.0%	R$ 31,265.52	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
S	20.00%
B/S	4.00
B + S	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

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Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			14,052	13,911	13,771	13,630	13,490	13,349	13,209	13,068	12,928	12,787
Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy												
Electricity price (R$/kWh)		0.625	0.664511917	0.7064426	0.751019148	0.798408	0.84878803	0.902347	0.959285	1.019815	1.084166	1.152577
Total generated electricity price (R$)			9337.721458	9827.6624	10342.25465	10882.66	11450.08262	12045.79	12671.08	13327.32	14015.92	14738.37
Income												
Total generated electricity price (R$)			9337.721458	9827.6624	10342.25465	10882.66	11450.08262	12045.79	12671.08	13327.32	14015.92	14738.37
Selling panels												16284.84
Total income			9337.721458	9827.6624	10342.25465	10882.66	11450.08262	12045.79	12671.08	13327.32	14015.92	31023.21
Expenses												
Initial investment		-39,082										
Variable costs												
Operating & Maintenance cost			-390.819	-415.4797	-441.696447	-469.567	-499.1972012	-530.697	-564.183	-599.783	-637.63	-677.864
Insurance			-117.2457	-124.6439	-132.508934	-140.87	-149.7591604	-159.209	-169.255	-179.935	-191.289	-203.359

Total expenses	-45,877	-39,082	-508	-540	-574	-610	-649	-690	-733	-780	-829	-881
Result												
Cash flow		-39,082	8,830	9,288	9,768	10,272	10,801	11,356	11,938	12,548	13,187	30,142
Cumulative cash flow		-39,082	-30,252	-20,965	-11,197	-924	9,877	21,233	33,170	45,718	58,905	89,047
Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.798801674	0.741171	0.687698817	0.638084	0.592049	0.549335	0.509703	0.47293
Contribution to NPV		-39,082	8192.632551	7995.7637	7802.734109	7613.476	7427.921753	7246.006	7067.665	6892.834	6721.451	14255.04
Net Present Value (NPV)		42,134										
Cumulative discount cash flow - discounted payback			-30,889	-22,894	-15,091	-7,477	-49	7,197	14,264	21,157	27,879	42,134

- Cooperative models – 10 households

GENERATION				
Power generator	Wp	14,300	Generated energy per month	1,952
Generated energy	kWh/year	23,424	delivery	1000
Annual lose	% a.a.	1.0%	labour	420
Finance			generator package	54,069.00
Initial investment	R$	61,038	44 panels	41756
Equipment investment (CAPEX)	R$/Wp	4.27		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 61,037.90	
Own equity	%	20.0%	R$ 12,207.58	each household R$ 1,220.76
Amount financed	%	80.0%	R$ 48,830.32	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
S	20.00%
B/S	4.00
B + S	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	**Present value**	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			23,424	23,190	22,956	22,721	22,487	22,253	22,019	21,784	21,550	21,316

Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy											
Electricity price (R$/kWh)		0.625	0.664511917	0.7064426	0.751019148	0.798408	0.84878803	0.902347	0.959285	1.019815	1.084166	1.152577
Total generated electricity price (R$)			15565.52714	16382.235	17240.03508	18140.86	19086.73038	20079.74	21122.07	22215.99	23363.86	24568.14
Income											
Total generated electricity price (R$)			15565.52714	16382.235	17240.03508	18140.86	19086.73038	20079.74	21122.07	22215.99	23363.86	24568.14
Selling panels											27558.96
Total income			15565.52714	16382.235	17240.03508	18140.86	19086.73038	20079.74	21122.07	22215.99	23363.86	52127.1
Expenses											
Initial investment		-61,038										
Variable costs											
Operating & Maintenance cost			-610.379	-648.8939	-689.839121	-733.368	-779.6434883	-828.839	-881.139	-936.739	-995.847	-1058.68
Insurance			-183.1137	-194.6682	-206.951736	-220.01	-233.8930465	-248.652	-264.342	-281.022	-298.754	-317.605
Total expenses	-71,650	-61,038	-793	-844	-897	-953	-1,014	-1,077	-1,145	-1,218	-1,295	-1,376
Result											

Cash flow		-61,038	14,772	15,539	16,343	17,187	18,073	19,002	19,977	20,998	22,069	50,751
Cumulative cash flow		-61,038	-46,266	-30,727	-14,384	2,804	20,877	39,879	59,856	80,854	102,923	153,674
Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.798801674	0.741171	0.687698817	0.638084	0.592049	0.549335	0.509703	0.47293
Contribution to NPV		-61,038	13706.2916	13377.447	13055.01084	12738.87	12428.91403	12125.03	11827.12	11535.06	11248.76	24001.56
Net Present Value (NPV)		75,006										
Cumulative discount cash flow - discounted payback			-47,332	-33,954	-20,899	-8,160	4,269	16,394	28,221	39,756	51,005	75,006

- Cooperative models – 20 households

GENERATION				
Power generator	Wp	29,700	Generated energy per month	4,054
Generated energy	kWh/year	48,648	delivery	2000
Annual lose	% a.a.	1.0%	labour	600
Finance			generator package	98,739.00
Initial investment	R$	111,473	90 panels	85410
Equipment investment (CAPEX)	R$/Wp	3.75		
Electricity tariff from Light	R$/kWh	0.625		
Discount rate	% a.a.	7.78%		
Financing				
Total amount	%	100%	R$ 111,472.90	
Own equity	%	20.0%	R$ 22,294.58	each household R$ 1,114.73
Amount financed	%	80.0%	R$ 89,178.32	
Interests on financing	% a.a.	4.00%	0.33%	% a.m.

B	80.00%
S	20.00%
B/S	4.00
B + S	1.00

Unleveraged Beta	0.47
Leveraged Beta	1.83
Km	17.79%
KRf	6.40%
Km-KRf	11.39%
Inflation	6.31%
Equity interest rate	27.28%
Debt interest rate	4.00%
WACC	7.78%
Tax rate	27.5%

Cash flow (profits & losses)			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Year	Present value	0	1	2	3	4	5	6	7	8	9	10
Production												
Energy (kWh) Generation			48,648	48,162	47,675	47,189	46,702	46,216	45,729	45,243	44,756	44,270
Inflation rate			6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%	6.31%
Cumulative inflation rate			6.31%	13%	20%	28%	36%	44%	53%	63%	73%	84%
Economy												
Electricity price (R$/kWh)		0.625	0.664511917	0.7064426	0.751019148	0.798408	0.84878803	0.902347	0.959285	1.019815	1.084166	1.152577
Total generated electricity price (R$)			32327.17574	34023.35	35804.86793	37675.75	39640.16648	41702.49	43867.24	46139.14	48523.1	51024.2
Income												
Total generated electricity price (R$)			32327.17574	34023.35	35804.86793	37675.75	39640.16648	41702.49	43867.24	46139.14	48523.1	51024.2
Selling panels												56370.6
Total income			32327.17574	34023.35	35804.86793	37675.75	39640.16648	41702.49	43867.24	46139.14	48523.1	107394.8
Expenses												
Initial investment		-111,473										
Variable costs												

Operating & Maintenance cost			-1114.729	-1185.068	-1259.84622	-1339.34	-1423.855025	-1513.7	-1609.21	-1710.76	-1818.7	-1933.47
Insurance			-334.4187	-355.5205	-377.953865	-401.803	-427.1565074	-454.11	-482.764	-513.227	-545.611	-580.04
Total expenses	-130,854	-111,473	-1,449	-1,541	-1,638	-1,741	-1,851	-1,968	-2,092	-2,224	-2,364	-2,514
Result												
Cash flow		-111,473	30,878	32,483	34,167	35,935	37,789	39,735	41,775	43,915	46,159	104,881
Cumulative cash flow		-111,473	-80,595	-48,112	-13,945	21,990	59,779	99,513	141,289	185,204	231,363	336,244
Interest rate q+1			108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Multiplier from interest load		1	0.927854024	0.8609131	0.798801674	0.741171	0.687698817	0.638084	0.592049	0.549335	0.509703	0.47293
Contribution to NPV		-111,473	28650.30256	27964.834	27292.711	26633.7	25987.55716	25354.07	24733	24124.13	23527.25	49601.48
Net Present Value (NPV)		172,396										
Cumulative discount cash flow - discounted payback			-82,823	-54,858	-27,565	-931	25,056	50,410	75,143	99,267	122,795	172,396